JOURNAL OF AGRICULTURAL RESEARCH

VOL. XXVI. WASHINGTON, D. C., DEC. 15, 1923 NO. 11

OILED WRAPPERS, OILS AND WAXES IN THE CONTROL OF APPLE SCALD[1]

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INTRODUCTION

It has been pointed out in earlier publications[2] that apple scald could be partly or entirely controlled by the application of various oils, fats, and waxes, either to the apple wrappers or to the apples themselves. The present paper reports the results of more complete and detailed studies on the relation of oils and waxes to the behavior of apples in storage.

STORAGE EXPERIMENTS WITH WRAPPERS

The results of five years' experiments with various kinds of wrappers are reported in Table I. It will be noted that the tests were made in various sections of the country and on varieties that are particularly susceptible to scald. The northwestern apples were mostly from the fancy grade and the eastern ones from the early pickings and greener lots. The eastern apples were packed in barrels and the northwestern ones in boxes and all were held in the local commercial storage plants, usually at a temperature of 32°. Unless otherwise stated they were wrapped on the date of picking and placed immediately in cold storage.

The scald values given show the general severity of the disease, allowance being made for the surface area scalded and the intensity of the scald, as well as the number of apples affected. Scald was not usually evident when the apples were removed from storage, but developed rapidly as the fruit became warm. The percentages of scald reported for eastern apples are based upon the condition of the fruit after being held for 3 days at 70° F., and those for northwestern apples on the condition of the fruit after 7 to 10 days at 55° to 60° F. In most cases the apples were held for later notes, the contrast between the fruit in the oiled wrappers and that in untreated wrappers becoming greater with the extension of the after storage period.

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
EASTERN APPLES.							
Grimes Golden, Vienna, Va., Sept. 18, 1918		(20)					
Unwrapped		38					
Unoiled wrapper		27					
Paraffin wrapper No. 1		18					
Paraffin wrapper No. 2		23					
Paraffin wrapper No. 3		15					
Mineral oil wrapper No. 1a		0					

[1] Accepted for publication Oct. 22, 1923.

[2] BROOKS, Charles, COOLEY, J. S., and FISHER, D. F. APPLE SCALD. *In* Jour. Agr. Research, v. 16, p. 195-217, 11 fig. 1919.

———. NATURE AND CONTROL OF APPLE SCALD. *In* Jour. Agr. Research, v. 18, p. 211-240, [illegible] 1919. Literature cited, p. 240.

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
EASTERN APPLES—continued							
Grimes Golden, Rockville, Md., Sept. 4, 1919	(31)	(13)					
Unwrapped	64	70					
Unoiled wrapper	80	83					
Glassine wrapper	35						
Paraffin wrapper No. 1	37	60					
Paraffin wrapper No. 2	16						
Mineral oil wrapper No. 1	0	0					
Mineral oil wrapper No. 1a	0						
Mineral oil wrapper No. 1b	0	0					
Mineral oil wrapper No. 2	0						
Mineral oil wrapper No. 3	0	0					
Grimes Golden, Arlington, Va., Sept. 10, 1920		(8)	(3)				
Unwrapped		3	15				
Mineral oil wrapper No. 3		0	0				
Mineral oil wrapper No. 3a		0	0				
Grimes Golden, Rockville, Md., Sept. 3, 1920	(18)	(8)					
Unwrapped	10	45					
Unoiled wrapper	12	66					
Mineral oil wrapper No. 3	0	0					
Mineral oil wrapper No. 4	0	0					
Grimes Golden, Charlestown, W. Va., Sept. 6, 1921		(19)			(13)		
Unwrapped		35			70		
Mineral oil wrapper No. 3a		0			0		
Mineral oil wrapper No. 4		0			15		
Mineral oil wrapper No. 4b		0			18		
Mineral oil wrapper No. 4c		30			38		
Mineral oil wrapper No. 5		2			22		
Mineral oil wrapper No. 6		0			20		
Mineral oil wrapper No. 7		0			6		
Grimes Golden, Rockville, Md., Sept. 6, 1922	(22)	(12)					
Unwrapped	40	49					
Unoiled wrapper		42					
Mineral oil wrapper No. 3a	0	1					
Mineral oil wrapper No. 10		3					
Mineral oil wrapper No. 11		1					
Mineral oil wrapper No. 11a		0					
Mineral oil wrapper No. 11b		0					
Mineral oil wrapper No. 11c		0					
Mineral oil wrapper No. 11d		2					
Mineral oil wrapper No. 11e		2					
Mineral oil wrapper No. 13		1					
York Imperial, Rockville, Md., Sept., 26, 1919		(15)		(5)			
Unwrapped		70					
Glassine wrapper		50					
Mineral oil wrapper No. 1		0		0			
Mineral oil wrapper No. 1b		0		0			
Mineral oil wrapper No. 2		0					
Mineral oil wrapper No. 3		0		0			
Wrappers with 60 per cent oil and 40 per cent paraffin mixture		0					
York Imperial, Leesburg, Va., Nov. 1, 1919		(17)					
Unwrapped		74					
Unoiled wrapper		69					
Mineral oil wrapper No. 1		4					
As above but 60 per cent oil and 40 per cent paraffin mixture		3					
York Imperial, Winchester, Va., Oct. 9, 1920			(1)	(5)		(14)	
Unwrapped			38	55		89	
Mineral oil wrapper No. 3a			0	0		0	
Mineral oil wrapper No. 4			0	0		0	
York Imperial, Arlington, Va., Sept. 27, 1920			(5)		(13)	(26)	
Unwrapped			45		58	84	
Unoiled wrapper			27		32	45	
Unoiled medicated wrapper			50			83	
Mineral oil wrapper No. 3			0		0	7	
Mineral oil wrapper No. 3a			0		0	3	
Mineral oil wrapper No. 4			0		1	7	

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
EASTERN APPLES—continued.							
York Imperial, Charlestown, W. Va., Sept. 20, 1921			(10)				
Unwrapped			16				
Unoiled wrapper			8				
Mineral oil wrapper No. 3			0				
Mineral oil wrapper No. 3a			0				
Mineral oil wrapper No. 4			4				
Mineral oil wrapper No. 4a			3				
Mineral oil wrapper No. 4b			3				
Mineral oil wrapper No. 4c			9				
Mineral oil wrapper No. 5			6				
Mineral oil wrapper No. 6			1				
Mineral oil wrapper No. 7			2				
York Imperial, Arlington, Va., Sept. 12, 1922		(29)					
Unwrapped		65					
Mineral oil wrapper No. 3a		5					
York Imperial, Rockville, Md., Oct. 2, 1922			(17)		(23)		
Unwrapped			40		70		
Unoiled wrapper			31		67		
Mineral oil wrapper No. 3a			0		4		
Mineral oil wrapper No. 10			1		5		
Mineral oil wrapper No. 11			0		5		
Mineral oil wrapper No. 11a			2		12		
Mineral oil wrapper No. 13			0		8		
York Imperial, Woodside, Del., Sept. 21, 1922			(6) (26)				
Unwrapped			25 46				
Unoiled wrapper			— 40				
Mineral oil wrapper No. 3a			— 2				
Mineral oil wrapper No. 11			— 7				
Mineral oil wrapper No. 11a			— 4				
Mineral oil wrapper No. 11b			— 6				
Mineral oil wrapper No. 11c			— 8				
Mineral oil wrapper No. 11d			— 15				
Mineral oil wrapper No. 11e			— 9				
Mineral oil wrapper No. 11f			— 15				
Mineral oil wrapper No. 13			— 6				
Mineral oil wrapper No. 13a			— 15				
York Imperial, Cornelia, Ga., Sept. 8, 1922			(5)				
Unwrapped			45				
Mineral oil wrapper No. 3a			0				
Stayman Winesap, Winchester, Va., Sept. 29, 1920		(6)	(1)	(5)		(14)	
Unwrapped		2	18	25		34	
Unoiled wrapper						26	
Unoiled medicated wrapper						31	
Mineral oil wrapper No. 3		0	0	0		0	
Mineral oil wrapper No. 3a		0	0	0		0	
Mineral oil wrapper No. 4		0	0	0		0	
Stayman Winesap, Rockville, Md., Oct. 7, 1920			(24)				
Unwrapped			25				
Mineral oil wrapper No. 3			0				
Mineral oil wrapper No. 3a			0				
Stayman Winesap, Charlestown, W. Va., Sept. 21, 1921			(13)				
Unwrapped			52				
Mineral oil wrapper No. 3a			4				
Mineral oil wrapper No. 4			16				
Mineral oil wrapper No. 4a			9				
Mineral oil wrapper No. 4b			10				
Mineral oil wrapper No. 4c			22				
Stayman Winesap, Woodside, Del., Sept. 28, 1922			(6) (26)				
Unwrapped			15 53				
Unoiled wrapper			— 22				
Tin foil			— 72				
Mineral oil wrapper No. 3a			— 2				
Mineral oil wrapper No. 11			— 10				
Mineral oil wrapper No. 11a			— 9				
Mineral oil wrapper No. 13			— 8				

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
EASTERN APPLES—continued.							
Arkansas (Mammoth Black Twig), Winchester, Va., Oct. 7, 1919		(10)	(2)	(23)			
Unwrapped		55	64	78			
Unoiled wrapper		38	59	76			
Mineral oil wrapper No. 1a		0	18	31			
Mineral oil wrapper No. 1		1	25	30			
As above but 60 per cent oil and 40 per cent paraffin mixture			16	31			
Arkansas (Mammoth Black Twig), Rockville, Md., Oct. 14, 1920			(24)			(26)	
Unwrapped			45			72	
Unoiled wrapper			48				
Mineral oil wrapper No. 3			0			4	
Mineral oil wrapper No. 3a			0			1	
Mineral oil wrapper No. 4			2				
Arkansas (Mammoth Black Twig), Middletown, Va., Oct. 20, 1920		(24)	(14)				
Unwrapped		32	51				
Mineral oil wrapper No. 3		0	0				
Mineral oil wrapper No. 3a		0	0				
Arkansas (Mammoth Black Twig), Winchester, Va., Oct. 18, 1920		(13) (24)				(26)	
Unwrapped		35 40				60	
Mineral oil wrapper No. 4		— 8				8	
Arkansas (Mammoth Black Twig), Rockville, Md., Oct. 5, 1922			(17)		(23)		
Unwrapped			75		90		
Mineral oil wrapper No. 3a			18		25		
Mineral oil wrapper No. 11a			22		30		
Mineral oil wrapper No. 11b			18		37		
Mineral oil wrapper No. 11c			21		35		
Mineral oil wrapper No. 11d			27		45		
Mineral oil wrapper No. 11e			18		50		
Mineral oil wrapper No. 11f			25		50		
Mineral oil wrapper No. 12			21		40		
Mineral oil wrapper No. 13			22		40		
Arkansas (Mammoth Black Twig), Martinsburg, W. Va., Oct. 26, 1922			(6) (21)		(23)		
Unwrapped			40 70		93		
Mineral oil wrapper No. 3a			— 1		15		
Mineral oil wrapper No. 11			— 7		18		
Mineral oil wrapper No. 11a			— 10		15		
Mineral oil wrapper No. 11b			— 6		19		
Mineral oil wrapper No. 11c			— 2		15		
Mineral oil wrapper No. 12			— 2		10		
Mineral oil wrapper No. 13			— 8		12		
Mineral oil wrapper No. 13a			— 1		10		
Yellow Newtown, Winchester, Va., Sept. 30, 1919				(1)	(12)		(12)
Unwrapped				0	15		78
Mineral oil wrapper No. 1				0	0		0
Mineral oil wrapper No. 1b				0	0		0
Mineral oil wrapper No. 2				0	0		0
Mineral oil wrapper No. 3				0	0		0
Rhode Island, Greening, Penn Yan, N. Y., Oct. 7, 1920			(15)	(19)			
Unwrapped			2	21			
Mineral oil wrapper No. 3			0	0			
Mineral oil wrapper No. 3a			0	0			
Mineral oil wrapper No. 4			0	0			
Rhode Island, Greening, Poughkeepsie, N. Y., Oct. 4, 1921				(29)			
Unwrapped				28			
Mineral oil wrapper No. 3a				0			
Mineral oil wrapper No. 3b				7			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 4b				2			
Mineral oil wrapper No. 4c				11			
Mineral oil wrapper No. 6				0			
Mineral oil wrapper No. 9				3			
NORTHWESTERN APPLES.							
Grimes Golden, Wenatchee, Wash., Sept. 24, 1919			(5)				
Unoiled wrapper			15				
Mineral oil wrapper No. 1			0				

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
NORTHWESTERN APPLES—continued							
Grimes Golden, Wenatchee, Wash., Sept. 20, 1920:							
Delayed in closed room till Oct. 14, 1920			(12)				
Unoiled wrapper			57				
Mineral oil wrapper No. 1			1				
Mineral oil wrapper No. 4			1				
Immediate storage—							
Unwrapped			7				
Unoiled wrapper			25				
Unoiled medicated wrapper			8				
Mineral oil wrapper No. 1			0				
Mineral oil wrapper No. 3a			0				
Mineral oil wrapper No. 4			0				
Grimes Golden, Wenatchee, Wash., Sept. 19, 1921				(1)			
Cellar storage—							
Unoiled wrapper				34			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 4b				0			
Mineral oil wrapper No. 8				0			
Cold storage—							
Unoiled wrapper				31			
Unoiled medicated wrapper				22			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 4b				0			
Mineral oil wrapper No. 4c				1			
Mineral oil wrapper No. 5				0			
Mineral oil wrapper No. 6				0			
Mineral oil wrapper No. 7				0			
Grimes Golden, Wenatchee, Wash., Sept. 13, 1922			(17)				
Cellar storage—							
Unoiled wrapper			54				
Unoiled medicated wrapper			14				
Mineral oil wrapper No. 4			1				
Mineral oil wrapper No. 7			1				
Mineral oil wrapper No. 12			1				
Mineral oil wrapper No. 13a			3				
Cold storage—							
Unoiled wrapper			36				
Unoiled medicated wrapper			14				
Mineral oil wrapper No. 4			1				
Mineral oil wrapper No. 6			1				
Mineral oil wrapper No. 7			0.5				
Mineral oil wrapper No. 11c			0				
Mineral oil wrapper No. 11f			0				
Mineral oil wrapper No. 12			0.4				
Mineral oil wrapper No. 13			0.7				
York Imperial, Wenatchee, Wash., Oct. 8, 1921					(22)		
Unoiled wrapper					47		
Unoiled medicated wrapper					25		
Mineral oil wrapper No. 3a					0		
Mineral oil wrapper No. 4					0		
Mineral oil wrapper No. 4a					1		
Mineral oil wrapper No. 4b					1		
Mineral oil wrapper No. 4c					2		
Mineral oil wrapper No. 5					1		
Mineral oil wrapper No. 6					0		
Mineral oil wrapper No. 7					0		
Mineral oil wrapper No. 9					0		
York Imperial, Wenatchee, Wash. Picked Oct. 19, 1922, stored Oct. 23, 1922					(19)		
Unoiled wrapper					51		
Mineral oil wrapper No. 4					1		
Mineral oil wrapper No. 7					1		
Mineral oil wrapper No. 11					0.5		
Mineral oil wrapper No. 11a					1		
Mineral oil wrapper No. 11c					0.5		
Mineral oil wrapper No. 11f					2		
Mineral oil wrapper No. 12					0.7		
Mineral oil wrapper No. 13a					1		

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
NORTHWESTERN APPLES—continued.							
Rome Beauty Wenatchee, Wash., Oct. 24, 1919. Stored Oct 31					(30)		
Unoiled wrapper					41		
Mineral oil wrapper No. 1					0		
Rome Beauty, Wenatchee, Wash., Oct. 20, 1920				(21)	(29)	(18)	
Unoiled wrapper				13	25	30	
Unoiled medicated wrapper						23	
Mineral oil wrapper No. 1				0	0	0	
Mineral oil wrapper No. 3a				0	0	0	
Mineral oil wrapper No. 4				0	0	0	
Rome Beauty, Wenatchee, Wash., Oct. 27, 1921					(22)		
Cellar storage—							
Unoiled wrapper					27		
Mineral oil wrapper No. 4					0		
Mineral oil wrapper No. 4a					3		
Cold storage—							
Unoiled wrapper					22		
Mineral oil wrapper No. 4a					0		
Mineral oil wrapper No. 4b					0		
Mineral oil wrapper No. 7					0		
Rome Beauty, Wenatchee, Wash., Oct. 6, 1922. Stored Oct. 10						(25)	
Cellar storage—							
Unoiled wrapper						55	
Mineral oil wrapper No. 4						3	
Mineral oil wrapper No. 7						3	
Mineral oil wrapper No. 11						1	
Mineral oil wrapper No. 11a						3	
Mineral oil wrapper No. 12						2	
Mineral oil wrapper No. 13						2	
Cold storage—							
Unoiled wrapper						10	
Mineral oil wrapper No. 4						0.3	
Mineral oil wrapper No. 7						0.8	
Mineral oil wrapper No. 10						2	
Mineral oil wrapper No. 11						0.7	
Mineral oil wrapper No. 11a						4	
Mineral oil wrapper No. 12						2	
Mineral oil wrapper No. 13						4	
Rome Beauty, Wenatchee, Wash., Oct. 19, 1922						(4)	
Unoiled wrapper						42	
Mineral oil wrapper No. 4						0	
Mineral oil wrapper No. 12						0	
Mineral oil wrapper No. 13						0	
Stayman Winesap, Wenatchee, Wash., Oct. 12, 1918				(24)			
Unwrapped				16			
Unoiled wrapper				19			
Glassine wrapper				47			
Paraffin wrapper No. 2				17			
Paraffin wrapper No. 3				11			
Mineral oil wrapper No. 1a				0			
Stayman Winesap, Wenatchee, Wash., Nov. 4, 1920				(7)		(23)	
Unoiled wrapper				2		16	
Mineral oil wrapper No. 1				0		0	
Mineral oil wrapper No. 3a				0		0	
Mineral oil wrapper No. 4				0		0	
Staymen Winesap, Wenatchee, Wash., Oct. 10, 1921				(18)			
Cellar storage—							
Unoiled wrapper				16			
Mineral oil wrapper No. 4a				7			
Cold storage, Nov. 3, 1921—							
Unoiled wrapper				16			
Unoiled medicated wrapper				15			
Mineral oil wrapper No. 4a				2			
Mineral oil wrapper No. 4b				0			
Minera oil wrapper No. 4c				1			
Mineral oil wrapper No. 7				0			

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
NORTHWESTERN APPLES—continued							
Stayman Winesap, Wenatchee, Wash., Oct. 25, 1922				(17)			
Cellar storage—							
Unoiled wrapper				9			
Mineral oil wrapper No. 7				0.5			
Mineral oil wrapper No. 12				0.1			
Mineral oil wrapper No. 13				0.1			
Cold storage—							
Unoiled wrapper				14			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 7				0			
Mineral oil wrapper No. 11				0.6			
Mineral oil wrapper No. 12				0			
Mineral oil wrapper No. 13				0			
Stayman Winesap, Wenatchee, Wash., Oct. 20, 1922						(4)	
Unoiled wrapper						24	
Mineral oil wrapper No. 4						0	
Mineral oil wrapper No. 11						0	
Mineral oil wrapper No. 12						0	
Mineral oil wrapper No. 13						0	
Delicious, Wenatchee, Wash., Sept. 29, 1921				(17)			
Cellar storage—							
Unoiled wrapper				3			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 4b				0			
Cold storage—							
Unoiled wrapper				6			
Mineral oil wrapper No. 4				0			
Mineral oil wrapper No. 4a				1			
Mineral oil wrapper No. 4b				0			
Mineral oil wrapper No. 7				0			
Arkansas (Mammoth Black Twig), Wenatchee, Wash., Nov. 1, 1920						(17)	
Unoiled wrapper						23	
Mineral oil wrapper No. 1						0	
Mineral oil wrapper No. 3a						0	
Mineral oil wrapper No. 4						0	
Arkansas (Mammoth Black Twig), Wenatchee, Wash., Oct. 25, 1921							(7)
Unoiled wrapper							18
Mineral oil wrapper No. 4							6
Mineral oil wrapper No. 4b							5
Mineral oil wrapper No. 4c							7
Mineral oil wrapper No. 5							4
Mineral oil wrapper No. 7							11
Mineral oil wrapper No. 8							4
Mineral oil wrapper No. 9							5
Arkansas (Mammoth Black Twig), Wenatchee, Wash., Nov. 2, 1922. Stored Nov. 7							(6)
Cellar storage—							
Unoiled wrapper							49
Mineral oil wrapper No. 4							15
Mineral oil wrapper No. 7							16
Mineral oil wrapper No. 12							7
Mineral oil wrapper No. 13							8
Cold storage							
Unoiled wrapper							45
Mineral oil wrapper No. 4							5
Mineral oil wrapper No. 7							7
Mineral oil wrapper No. 10							0
Mineral oil wrapper No. 12							0
Mineral oil wrapper No. 13							5
White Pearmain, Wenatchee, Wash., Oct. 4, 1921							(7)
Unoiled wrapper							29
Mineral oil wrapper No. 4							0
Mineral oil wrapper Nol 4a							3
Mineral oil wrapper Nol 4b							0
Mineral oil wrapper No. 4c							6
Mineral oil wrapper No. 6							0
Mineral oil wrapper No. 7							0

TABLE I.—*The effect of oil, paraffin, and other wrappers upon the development of scald*—Continued

Variety, locality of orchard, date of picking, and kind of wrapper.	Percentage of scald on dates shown by numbers in parentheses.						
	December.	January.	February.	March.	April.	May.	June.
NORTHWESTERN APPLES—continued.							
White Pearmain, Wenatchee, Wash., Oct. 12, 1922					(3)		
Unoiled wrapper					12		
Mineral oil wrapper No. 4					0		
Mineral oil wrapper No. 7					0		
Mineral oil wrapper No. 11					0		
Mineral oil wrapper No. 11a					0		
Mineral oil wrapper No. 12					0		
Mineral oil wrapper No. 13					0		
Arkansas Black, Wenatchee, Wash., Oct. 21, 1920							(20)
Unoiled wrapper							9
Mineral oil wrapper No. 1							0
Mineral oil wrapper No. 3a							0
Mineral oil wrapper No. 4							0
Arkansas Black, Wenatchee, Wash., Oct. 25, 1921							[illegible]
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 4							0
Mineral oil wrapper No. 4a							[illegible]
Mineral oil wrapper No. 4b							0
Mineral oil wrapper No. 4c							[illegible]
Arkansas Black, Wenatchee, Wash., Picked Nov. 4, 1922, stored Nov. 7							[illegible]
Cellar storage—							
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 4							0
Mineral oil wrapper No. 7							0
Mineral oil wrapper No. 12							[illegible]
Mineral oil wrapper No. 13							[illegible]
Cold storage—							
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 7							[illegible]
Mineral oil wrapper No. 12							[illegible]
Mineral oil wrapper No. 13							[illegible]
Yellow Newtown, Wenatchee, Wash., Oct. 21, 1921							[illegible]
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 4							[illegible]
Mineral oil wrapper No. 4a							[illegible]
Mineral oil wrapper No. 4b							[illegible]
Mineral oil wrapper No. 4c							[illegible]
Winesap, Wenatchee, Wash., Oct. 25, 1920							[illegible]
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 3a							[illegible]
Mineral oil wrapper No. 4							[illegible]
Winesap, Wenatchee, Wash., Oct. 13, 1921. Cellar storage						[illegible]	
Unoiled wrapper						6	
Mineral oil wrapper No. 4						0	
Mineral oil wrapper No. 4a						1	
Mineral oil wrapper No. 4b						0	
Mineral oil wrapper No. 4c						0	
Mineral oil wrapper No. 5						0	
Mineral oil wrapper No. 7						0	
Mineral oil wrapper No. 8						0	
Winesap, Wenatchee, Wash., Oct. 25, 1921. Cold storage							[illegible]
Unoiled wrapper							[illegible]
Mineral oil wrapper No. 3a							0
Mineral oil wrapper No. 4							[illegible]
Mineral oil wrapper No. 4a							0
Mineral oil wrapper No. 4b							0
Mineral oil wrapper No. 4c							[illegible]
Mineral oil wrapper No. 5							0
Mineral oil wrapper No. 6							0
Mineral oil wrapper No. 7							0
Mineral oil wrapper No. 8							0
Mineral oil wrapper No. 9							[illegible]
Winesap, Wenatchee, Wash., Oct. 19, 1922						(26)	
Unoiled wrapper						6	
Mineral oil wrapper No. 4						0	
Mineral oil wrapper No. 7						0	
Mineral oil wrapper No. 11						0	
Mineral oil wrapper No. 12						0	
Mineral oil wrapper No. 13						0	

UNOILED WRAPPERS

The tests with apples in the usual commercial wrappers as compared with unwrapped apples show that these unoiled wrappers have practically no effect upon scald control. In the tests of Table I where the two conditions were compared the average degree of scald on the wrapped apples was 41 per cent and that on the unwrapped ones 42 per cent.

UNOILED MEDICATED WRAPPERS

The unoiled medicated wrappers were purchased in the northwestern market where they have been extensively sold on the ground that they have great preservative qualities. The average results of the comparable tests in the preceding table show 33 per cent of scald on the apples in unoiled wrappers and 23 per cent on the apples in unoiled medicated wrappers.

PARAFFIN WRAPPERS

Paraffin wrapper No. 1 was made by soaking the usual commercial apple wrapper in hot paraffin; paraffin wrappers No. 2, 3, and 4 were supplied by paper companies; No. 2 was a heavy grade of paper and No. 3 and 4 tissue grades similar to the paper used for wrapping lunches and apparently infiltrated with a low melting point paraffin or a mixture of paraffin and oil.

The paraffin wrappers have reduced the percentage of scald in all cases, but have shown only about half the efficiency of the mineral oil wrappers. An average for the comparable tests shows 42 per cent of scald on the apples in unoiled commercial wrappers, 20 per cent on the apples in the paraffin wrappers and no scald for those in mineral oil wrappers.

MINERAL OIL WRAPPERS

EFFECT UPON SCALD

The scald control secured with the mineral oil wrappers is shown in detail in Table I and the relative efficiency of the various wrappers is brought out more clearly in Table II. In most cases these wrappers either entirely prevented the disease or reduced it to such an extent that it was no longer of importance from the market standpoint. In the total of 67 experiments there were four instances that probably should be noted as exceptions to this rule; two with eastern grown Stayman Winesap and two with eastern grown Arkansas (Mammoth Black Twig). In the 1921 and 1922 experiments with Stayman Winesap scald was reduced from more than 50 per cent on the unwrapped fruit to 4 to 16 per cent on the fruit in the better grade of oil wrappers. In the 1919 experiment with Arkansas scald was held in complete control by the oiled wrappers until January 10, when the unwrapped fruit showed 55 per cent of the disease, but by February 2 the apples in oiled wrappers had developed 18 to 25 per cent of scald as compared with 64 per cent on the unwrapped apples. In the 1922 experiment on Arkansas from Rockville, Md., the apples in oiled wrappers had developed about 20 per cent of scald by February 17, while those that were unwrapped had 75 per cent. These results with Stayman Winesap and Arkansas would appear to be fairly satisfactory when compared with the average data from disease-control measures, but they fall considerably short of the control secured in other oiled wrapper experiments, and in the case of the Arkansas the disease was not held sufficiently in check to prevent the apples from being offered at a discount in price.

TABLE II.—*Relative efficiency of mineral oil wrappers in the control of apple scald*

Variety of apples and date of note taking.	Percentage of scald.																											
	Check, no oil.	Mineral oil wrappers.																										
		1	1a	1b	2	3	3a	3b	4	4a	4b	4c	5	6	7	8	9	10	11	11a	11b	11c	11d	11e	11f	12	13	13a
Grimes Golden, eastern:																												
Dec. 20, 1918	27		0																									
Jan. 13, 1920	83	0		0		0																						
Feb. 3, 1921	15					0	0																					
Jan. 8, 1921	66					0			0																			
Jan. 19, 1922	35						0		0		0	30	2	0	0													
Apr. 13, 1922	70						0		15		18	38	22	20	6													
Jan. 12, 1923	49						1											3	1	0	0	0	2	2			1	
Grimes Golden, northwestern:																												
Feb. 12, 1921—																												
Delayed storage	67	1							1																			
Immediate storage	25	0					0		0																			
Mar. 1, 1922—																												
Cellar storage	34								0		0					0												
Cold storage	31								0		0	1	0	0	0													
Feb. 17, 1923—																												
Cellar storage	54								1						1											1		3
Cold storage	36								1					1	0.5							0			0	0.4		0.7
York Imperial, eastern:																												
Jan. 15, 1920	70	0		0	0	0																						
Mar. 5, 1920		0		0		0																						
Jan. 17, 1920	69	4																										
May 14, 1921	89						0		0																			
Apr. 13, 1921	32					0	0		1																			
May 26, 1921	45					7	3		7																			
Feb. 10, 1922	8					0	0		4	3	3	9	6	1	2													
Jan. 29, 1923	65						5																					
Feb. 5, 1923	45						0											1	0	2							0	
Feb. 17, 1923	40						0												7	4	6	8	15	9	15		6	15
Feb. 26, 1923	46						2																					
York Imperial, northwestern:																												
Apr. 22, 1922	47						0		0	1	1	2	1	0	0		0											
Apr. 19, 1923	51								1						1				0.5	1		0.5			2	0.7		1
Stayman Winesap, eastern:																												
Feb. 24, 1921	25					0	0																					
May 14, 1921	26					0	0		0																			
Feb. 13, 1922	52						4		16	9	10	22							10	9							8	
Feb. 26, 1923	53						2																					

Stayman Winesap, northwestern:																												
Mar. 24, 1919	19	0																										
May 23, 1921	16	0					0		0																			
Mar. 18, 1922	16									2	0	1			0													
Mar. 17, 1923—																												
Cellar storage	9														0.5											0.1	0.1	
Cold storage	14								0						0				0.6							0	0	
May 4, 1923	24								0										0							0	0	
Rome Beauty, northwestern:																												
Apr. 30, 1920	41	0																										
May 18, 1921	30	0					0		0																			
Apr. 22, 1922—																												
Cellar storage	27								0	3																		
Cold storage	22									0	0				0													
May 4, 1923	42								0																	0	0	
May 25, 1923—																												
Cellar storage	55								3						3				1	3						2	2	
Cold storage	10								0.3						0.8			2	0.7	4						2	4	
Delicious, northwestern: Mar. 17, 1922	6								0	1	0				0													
Arkansas, eastern:																												
Mar. 23, 1920	76	31	30																									
May 26, 1921	72					4	1																					
Feb. 14, 1921	51					0	0																					
Feb. 17, 1923	75						18													22	18	21	27	18	25	21	22	
Feb. 21, 1923	70						1												7	10	6	2				2	8	1
Arkansas, northwestern:																												
May 17, 1921	23	0					0		0																			
June 7, 1922	18								6		5	7	4		11	4	5											
June 6, 1923—																												
Cellar storage	49								15						16											7	8	
Cold storage	45								5						7			0								0	5	
White Pearmain, northwestern:																												
June 7, 1922	29								0	3	0	6		0	0													
Apr. 3, 1923	12								0						0				0	0						0	0	
Arkansas Black, northwestern:																												
June 20, 1921	9	0					0		0																			
June 14, 1922	7								0	1	0	2																
June 8, 1923—																												
Cellar storage	18								0.2						0											0	0	
Cold storage	5														0											0	0	
Yellow Newtown, eastern: June 12, 1920	78	0		0	0	0																						
Yellow Newtown, northwestern: June 14, 1922	33								8	3	3	2																
Rhode Island Greening, eastern:																												
Mar. 19, 1921	21					0	0		0																			
Mar. 29, 1922	28						0	7	0		2	11		0			3											
Winesap, northwestern:																												
June 20, 1921	9						0		0																			
May 20, 1922, cellar storage	6								0	1	0	0	0	0	0	0												
June 14, 1922	30						0		9	0	0	3	0	0	0	0	0											
May 26, 1923	6								0						0				0							0	0	

A study of the data from the experiments reported in Table I, in which fruit was withdrawn at different times in the storage season, shows that the oiled wrappers have delayed scald 4 to 12 weeks on Grimes, 8 to 18 weeks on York Imperial, 10 or more weeks on Rome Beauty, 5 to 17 weeks on Stayman Winesap, and 4 to 15 weeks on Arkansas (Mammoth Black Twig). The fruit that was unwrapped or in unoiled wrappers became more seriously scalded with the advance of the storage season, while that which was in oiled wrappers usually remained practically or entirely free from scald, the apples finally breaking down from old age or some other cause. The apples in oiled wrappers were usually firmer and crisper than those in unoiled wrappers.

SOURCE AND PREPARATION OF OILED WRAPPERS

Mineral oil wrappers Nos. 1, 1a, and 1b were treated with an oil having a yellow color and a slight odor of kerosene. The oil was of paraffin origin and was purchased from an eastern oil company having large holdings in the South Central States. Wrapper No. 1 was prepared by applying hot oil to the usual 14-pound commercial apple wrappers and removing the excess of oil by stacking the oiled wrappers between unoiled ones. The final wrappers carried 17 to 25 per cent of their weight of oil. Wrappers No. 1a and 1b were supplied by a paper company; No. 1a was a very heavy grade of oiled paper and No. 1b a similar paper of medium weight, yet far too heavy for commercial apple wrapping.

Wrapper No. 2 was hand oiled, as described for No. 1 with a similar oil from the same source, but having a higher viscosity.

Wrappers No. 3, 3a, and 3b were treated with an oil that was similar to those used on Nos. 1 and 2 and of the same origin, but it had a higher specific gravity and a deeper color. Wrapper No. 3 was hand oiled, as described for No. 1. Wrapper No. 3a was a specially prepared apple wrapper purchased from an eastern paper company. See description in Table III.

Wrapper No. 3b was a specially prepared apple wrapper purchased from a western company. It was a 14-pound paper carrying 11 per cent of oil.

Wrappers Nos. 4, 4a, 4b, and 4c were treated with an odorless, tasteless, colorless oil derived from a paraffin base and refined by an eastern oil company. Wrapper No. 4 was hand oiled, as described for No. 1. Wrapper No. 4a was a special apple wrapper prepared by the same company that prepared No. 3b. It was a 14-pound paper carrying 1[illegible] per cent of oil, or about 22 grams to 100 wrappers. Wrapper No. 4b was a special apple wrapper prepared by a middle west paper company. It was a 12-pound paper carrying 14 per cent of oil, or about 23 grams to each 100 wrappers. Wrapper No. 4c was from the same company as No. 4b, but it carried only 4 per cent of oil, or about 6 grams to each 100 wrappers.

Wrapper No. 5 was hand oiled, as described for wrapper No. 1, but with an odorless, tasteless, colorless oil a little heavier than that used on wrapper No. 4 and marketed by the same oil company.

Wrapper No. 6 was hand oiled, as described for No. 1, but with an odorless, tasteless, colorless oil a little lighter than that used on wrapper No. 4, derived from a paraffin base and marketed by a middle west oil company.

Wrapper No. 7 was hand oiled, as described for No. 1, but with an odorless, tasteless, colorless oil derived from an asphalt base and marketed by a Pacific coast oil company.

Wrapper No. 8 was an oiled, medicated wrapper marketed by the same company as the unoiled medicated wrapper already described. It had been treated with the same oil that was used on wrapper No. 7 and carried 15 per cent of its weight of oil.

Wrapper No. 9 was a specially prepared wrapper sold by the same company as 3a; it had been treated with an odorless, tasteless, colorless oil combined with a small amount of paraffin and carried about 18 per cent of the two combined.

Wrapper No. 10 was apparently very similar to wrapper No. 9 but it was prepared by a middle west paper company.

Wrappers No. 11, 11a, 11b, 11c, 11d, 11e, and 11f were prepared by an eastern paper company and were treated with the same oil as wrapper No. 4. Wrapper No. 11 was from 14-pound paper, and No. 11a from 12-pound paper, both guaranteed to contain as much as 22 per cent of oil. See Table III. Wrappers 11b, 11c, 11d, 11e, and 11f were guaranteed to contain 30, 25, 20, 18, and 15 per cent of oil, respectively. They were prepared by the paper company for experimental use.

Wrapper No. 12 was prepared by a New England paper company. It was a 14-pound paper and treated with the same oil as wrapper No. 4. See Table III.

Wrappers No. 13 and 13a were prepared by the same company as wrapper No. 4b and 4c. No. 13 was a 14-pound paper carrying 24 per cent of oil and No. 13a a 12-pound paper. See Table III for oil content.

RELATIVE EFFICIENCY OF OILS

All of the oils used have given good scald control. A comparison of the results with the hand-oiled wrappers Nos. 1, 2, 3, 4, 5, 6, and 7, as shown in Table II, might suggest some slight contrast in efficiency, but perhaps not enough to be of practical importance and beyond experimental error.

DOSAGE OF OIL IN THE WRAPPER

Experiments have shown that wrappers with free oil on their surface may sometimes cause slight injury to the skin of the apple, but fortunately such excessively oiled wrappers are impractical for general use on account of the wrappers sticking together. The hand-oiled wrappers used in the previously reported experiments had from 17 to 25 per cent of oil, or practically all the paper would carry. These wrappers gave good scald control and caused no injury, but the most completely saturated ones sometimes delayed the natural yellowing of the ground color of the apples, making them appear abnormally green at the time of removal from storage. The dosage of oil in the commercial or machine-made wrappers ranged from 4 to 30 per cent. The wrappers with 4 per cent of oil have sometimes given good scald control but under severe tests have been an almost complete failure. Wrappers carrying 11 and 12 per cent of oil have given good results on western apples and fair on eastern, but where apples have been held rather late there have been indications that these wrappers had about reached their limit in scald control. Commercial wrappers carrying 15 per cent or more of oil (about 28 grams to each 100 wrappers) have given good scald control with no objectionable results.

RETENTION OF OIL BY THE WRAPPERS

A study was made of the extent to which the various oiled wrappers gave up their oil to the apples or to other objects with which they came in contact. Oil determinations were made on fresh unused wrappers, on similar wrappers after removal from apples at the end of the storage period, and on the box-liners from the same packages. Tests were also made on the freedom with which the various wrappers gave up their oil to sheets of blotting paper, the oil content of fresh wrappers being compared with that of similar wrappers that had been held between sheets of blotting paper under 10 pounds pressure for 48 hours. The oil determinations were made by petroleum ether extraction with the Soxhlet apparatus. The preliminary work was done by the writers and the results checked up and confirmed by determinations made by Dr. G. S. Jamieson and Mr. W. F. Baughman of the oil, fat, and wax laboratory, Bureau of Chemistry. All percentages are computed on the dry weight of the oiled paper. The results are reported in Table III.

TABLE III.—*Dosage of oil in the wrapper: retention of oil*

Wrappers.			Dosage of oil on fresh wrappers.		Dosage of oil after use on the apples. Gm. of oil per wrapper.		Dosage of oil after 48 hours between blotters. Gm. of oil per wrapper.		Dosage of oil in box liners after use in contact with oiled wrappers.	
Number.	Weight of paper.	Size.	Per cent.	Gm. per wrapper.	Retained.	Lost.	Retained.	Lost.	Per cent.	Gm. per box.
3a	14-lb.	10 x 10	21.3	0.4097	0.3436	0.0661	0.0620	0.3477	9.6	4.0512
11	14-lb.	10 x 10	24.4	.4481	.3875	.0606	.0763	.3718	13.6	5.2820
11a	12-lb.	10 x 10	26.3	.4356	.3638	.0718	.0687	.3669	7.7	2.7893
12	14-lb.	10 x 10	14.2	.3191	.2640	.0551	.0625	.2566	4.9	2.1016
13a	12-lb.	10 x 10	16.7	.2528	.2080	.0448	.0478	.2050	10.1	7.5750
Average				.3731	.3134	.0597	.0635	.3096		4.3598

The data reported in Table III show some contrast in the freedom with which the different wrappers gave up their oil during storage and a still greater contrast in the freedom with which they released their oil to dry blotters. A comparison of these data with that reported in Table II, however, gives little evidence of correlation between the freedom with which the wrappers released their oil and their efficiency in scald control. The average loss of oil by the wrappers during storage was approximately 0.0597 gm. per wrapper. The amount taken up by the liners varied widely but averaged 4.3598 gm. per box. With a box containing 113 apples this would mean that the liner had taken an average of 0.0386 gm. of oil from each wrapper, leaving 0.0211 gm. of the above loss to be accounted for by passage to the apples, to the box, and to other objects.

In order to obtain further evidence in regard to the action of the oil, apples were wrapped in one or more unoiled wrappers and oiled wrappers applied outside of these. The fruit was thus largely protected from the oil, yet kept in close proximity to it. The resulting scald control is shown in Table IV.

The average degree of scald reported in Table IV for the apples that were unwrapped or in unoiled wrappers is 39 per cent, and the average for the apples in oiled wrappers 2.7 per cent, while the average where one unoiled wrapper was used inside of an oiled one is 4.9 per cent, and

1e average where two or three unoiled ones were used inside an oiled ne is somewhat higher. The results indicate that the efficiency of the iled wrappers in scald control was decreased by placing unoiled wrappers etween them and the apples. This decrease, however, is extremely mall when compared with the percentage of scald on the untreated fruit.

Oil determinations were made on the wrappers that had been used in he above experiments, and the results are reported in Table V. All ercentages are based on the dry weight of the oiled paper.

TABLE IV.—*Effect of unoiled wrappers inside of oiled ones*

Variety, locality, and period of storage.	Oiled wrapper used.	Percentage of scald.					
		Unwrapped or in unoiled wrapper.	Oiled wrapper.	One oiled wrapper outside of one unoiled wrapper.	One oiled wrapper outside of two unoiled wrappers.	One oiled wrapper outside of three unoiled wrappers.	Two oiled wrappers outside of one unoiled wrapper.
Grimes Golden, Rockville, Md., Sept. 6, 1922, to Jan. 12, 1923	No. 3a	49	1	4	2	......	......
Grimes Golden, Wenatchee, Wash., Sept. 13, 1922 to Feb. 17, 1923	No. 13a	36	.7	1	......	......	1.3
York Imperial, Arlington, Va., Sept. 12, 1922, to Jan. 29, 1923	No. 3a	65	5	8	18	20	......
York Imperial, Woodside, Del., Sept. 21, 1922, to Feb. 26, 1923	No. 13	46	6	7	......	......	......
York Imperial, Rockville, Md., Oct. 2, 1922, to Feb. 17, 1923	No. 11	40	0	1	......	......	......
York Imperial, Wenatchee, Wash., Oct. 23, 1922, to Apr. 19, 1923	No. 4	51	1	5	......	......	......
ayman Winesap, Woodside, Del., Sept. 28, 1922, to Feb. 26, 1923	No. 3a	53	2	6	......	......	......
	No. 11	53	10	18	......	......	......
ayman Winesap, Wenatchee, Wash., Oct. 25, 1922, to Mar. 17, 1923	No. 12	14	0	0	......	......	0
ome Beauty, Wenatchee., Wash., Oct. 10, 1922, to May 25, 1923	No. 13	10	4	4	......	......	15
hite Pearmain, Wenatchee, Wash., Oct. 12, 1922, to Apr. 3, 1923	No. 13a	12	0	0	......	......	0
Average results	....	39	2.7	4.9	......	......	......

The fresh oiled wrappers averaged 0.3574 gm. of oil per wrapper nd those that had been used outside of one unoiled wrapper averaged .2539 gm. per wrapper, making an average loss during storage of 0.1035 m. per wrapper. Of this loss, 0.0678 gm. passed over to the unoiled rappers, and if the movement to the liners was approximately as great s where single wrappers were used the remaining 0.0357 gm. is fully ccounted for in loss to the liners. In the experiments where two noiled wrappers were used inside the oiled one the fresh oiled rappers had 0.4097 gm. of oil per wrapper, the used ones 0.3062 gm, nd the unoiled ones after use a total of 0.0836 gm., leaving but 0.0199

gm. loss from each set of wrappers. This loss can be fully accounted for, as explained above, in passage of oil to the liners. There was no indication of oil on the apples, and if any passed over to them in either set of experiments it must have been the merest trace.

TABLE V.—*Dosage of oil in the various wrappers before and after use in experiment reported in Table IV*

Make of oiled wrapper.	Gm. of oil in fresh wrapper.	Two unoiled wrappers inside of an oiled wrapper. Gm. of oil per wrapper after use.			One unoiled wrapper inside of an oiled one. Gm. of oil per wrapper after use.	
		Oiled wrapper.	Unoiled wrapper next to oiled one.	Unoiled wrapper next to apple.	Oiled wrapper.	Unoiled wrapper.
3a	0.4097	0.3062	0.0608	0.0228	0.3181	0.069
11	.4481				.2860	.103
12	.3191				.2441	.039
13d	.2528				.1673	.062
Average results	.3574				.2539	.067

EFFECT OF OILED WRAPPERS ON UNWRAPPED FRUIT OF THE SAME PACKAGE

In a number of experiments only a part of the apples of the package were in oiled wrappers, the others being held either unwrapped or in unoiled wrappers. Table VI shows the scald control secured under these conditions. The eastern apples were packed in barrels with part of the apples unwrapped and the northwestern ones in boxes with part of the apples in oiled wrappers and part in unoiled ones.

TABLE VI.—*Partial control of scald on apples that were unwrapped or in unoiled wrappers but packed with apples that were in oiled wrappers*

Variety, locality, and the date of taking notes.	Percentage of scald. In package with no oil.	In packages with part of the apples in oiled wrappers. Apples two or more layers distant from oiled wrappers.	Apples adjacent to oiled wrappers.	Apples in oiled wrappers.
EASTERN APPLES.				
Grimes Golden:				
Jan. 20, 1919	38	20	12	0
Jan 13, 1920	70	52	21	0
Arkansas, Jan. 10, 1920	55		15	1
York Imperial, Jan. 15, 1920	70	46		0
NORTHWESTERN APPLES.				
Grimes Golden, Jan. 17, 1923	38	18	4	1
Stayman Winesap, Mar. 19, 1923	11	13	2	0
Average	47	29.8	10.8	0.

The data reported in Table VI indicate that when part of the apples of a package are in oiled wrappers and part unwrapped or in unoiled wrappers, the oiled wrappers cause a very definite decrease in scald on the adjacent apples and have a favorable effect on the ones that are several layers away.

OIL WITHOUT THE WRAPPER

Experiments were made in which oiled blotter material was cut into narrow strips and scattered through the barrel of apples. Seven large blotter sheets carrying approximately 700 gm. of oil were used in each barrel. A description of the different oils has already been given in connection with the wrappers having the corresponding numbers. The results of the experiments are reported in Table VII.

TABLE VII.—*Effect of oiled blotter strips on apple scald*

Variety of apple and date of note taking.	Percentage of scald.			
	In barrels with no oil.	In barrels with oiled blotter strips.		
		Oil No. 1.	Oil No. 2.	Oil No. 3.
Grimes Golden, Dec. 31, 1919	64	26	28	21
York Imperial:				
Jan. 15, 1920	70	5	16	....
Jan. 17, 1920	74	....	....	12
Arkansas, Jan. 10, 1920	55	32	....	....

The fruit packed with the oiled blotter material scattered through the barrel averaged about one-third as much scald as that packed in the usual manner. While the results are not particularly satisfactory from the commercial standpoint, they show that scald can be reduced without inclosing the apples in wrappers.

Experiments were also made in which barrels were soaked in oil and others in which barrels were lined with oiled blotter sheets. In both cases the scald was reduced on the fruit nearest the oil but the results in general were even less satisfactory than those reported in Table VII for the oiled blotter strips.

A large number of experiments were made in the application of oil and wax directly to the skin of the apple. The material was rubbed on with a piece of cloth at the time the apples were packed. A description of the different oils has already been given in connection with the wrappers having the corresponding numbers. The heavily oiled apples received approximately 0.06 gm. of oil to the apple, the medium oiled ones approximately 0.03 gm. and the lightly oiled ones 0.017 gm. The B1 wax was composed of 75 parts by weight of mineral oil and 25 parts beeswax, the B2 of 50 parts mineral oil and 50 parts beeswax, and the B3 of 25 parts mineral oil and 75 parts beeswax. These waxes were applied at the rate of approximately 0.04 gm. to the apple. The P wax was composed of mineral oil and hard paraffin in equal parts by weight, and the treated fruit received approximately 0.035 gm. per apple. The V wax was composed of mineral oil and vaseline in equal parts by weight, and it was applied at the rate of approximately 0.03 gm. per apple. The BP1 wax

TABLE VIII.—*Partial control of scald by means of oils and waxes applied directly to the apple*

Variety and date of note taking.	Percentage of scald.																								
	No treatment.	Mineral-oil wrappers.	With oils.															With waxes.							
			No. 1.			No. 3.			No. 4.			No. 5		No. 6.		No. 7.									
			Heavy.	Medium.	Light.	Heavy.	Medium.	Light.	Heavy.	Medium.	Light.	Heavy.	Light	Heavy.	Light.	Heavy.	Light.	B1.	B2.	B3.	P.	V.	BP1.	BP2.	BP3.
Grimes Golden, Jan. 8, 1921	45	0	20		42	3		15	18		52														
Grimes Golden, Mar. 30, 1921	87	0	29		30				42		31														
Grimes Golden, Jan. 19, 1922	35	0							12			31		12		8			24		4	8			
Grimes Golden, Jan. 12, 1923	52	1																					42		45
York Imperial, Apr. 13, 1921	58	0	7			2	3	5	7	9	13														
York Imperial, Feb. 10, 1922	16	0	0						1		4	3	1	1	1	0	2	6	5	2	1	1			
York Imperial, Mar. 29, 1922	10	0										2	3			5	4		2						
York Imperial, Jan. 29, 1923	65	5																					31		
York Imperial, Feb. 17, 1923	40	0																					6	15	20
York Imperial, Feb. 26, 1923	46	2																					37	37	42
Stayman Winesap, Feb. 24, 1921	25	0							8		5														
Stayman Winesap, Mar. 5, 1921	25	0		5						1															
Stayman Winesap, May 23, 1921	16	0		6						2															
Stayman Winesap, Feb. 13, 1922	52	4							15		28			8	25			15	8	7					
Stayman Winesap, Feb. 26, 1923	53	2																					18	11	10
Baldwin, Mar. 29, 1922	16	1							2		2							1	5						
Rome Beauty, May 18, 1921	30	0		5						4															
Arkansas, Jan. 24, 1921	32	0				3	2	10	2	2	5														
Arkansas, Feb. 24, 1921	45	0				3		4	3		19														
Arkansas, May 17, 1921	23	0		18						20															
Arkansas, May 26, 1921	72	1				23		25	28		59														
Arkansas, Feb. 17, 1923	75	18																					30	26	21
Arkansas, Feb. 21, 1923	70	1																					70	63	74
Arkansas Black, June 20, 1921	9	0		19						8															
Rhode Island Greening, Mar. 29, 1922	28	0							1		1					4		0	4						

was composed of 40 parts by weight of mineral oil, 5 parts beeswax, and 55 parts paraffin. The BP2 wax was composed of 40 parts of mineral oil, 10 parts beeswax, and 50 parts paraffin. The BP3 wax was composed of 29 parts mineral oil, 10 parts beeswax, and 61 parts paraffin. Approximately 0.018 gm. of the beeswax-paraffin-oil mixtures was applied to each apple. The relatively low dosage in this case was due to the fact that these waxes were comparatively firm and did not stick to the fruit in as heavy layers as the other waxes. The results of the various oil and wax experiments are reported in Table VIII.

In most cases the apples that were treated with oil had a less attractive appearance upon removal from storage than the untreated ones. The natural bloom of the fruit was lacking, and the apples that had received heavy or medium applications of oil, and many of them that had received light ones, still had an oily appearance. The apples that received the beeswax-oil, paraffin-oil, or vaseline-oil mixtures were usually slightly sticky or greasy, but those that received the beeswax-paraffin-oil combinations had little that was objectionable in feel or appearance.

Many of the lots treated with oil and a few of those treated with beeswax-oil mixtures had a higher percentage of blue mold rot than the untreated fruit.

Most of the apples that were treated with either oil or wax were much greener and firmer than the untreated fruit and were often lacking in flavor and quality. The condition of the fruit was much like that described in an earlier publication [3] as resulting from short periods of storage in carbon dioxide. The fruit that received heavy or medium applications of oil was affected most, that which received light applications of oil or was treated with beeswax-oil, paraffin-oil, or vaselin-oil mixtures was less affected, while that which was treated with the beeswax-paraffin-oil mixtures was entirely normal in color, firmness, and taste.

A study of Table VIII shows that all of the oils and most of the waxes decreased the development of scald but that they fell far short of the oiled wrappers in efficiency. If an average is taken of the comparable tests, it gives 14.7 per cent of scald on the lightly oiled apples, 9.1 per cent on the heavily oiled ones, 40.5 per cent on the untreated fruit, and 0.5 per cent on the apples in mineral-oil wrappers. The beeswax-oil, paraffin-oil, and vaseline-oil mixtures gave approximately as good results as the heavy applications of oil, but the beeswax-paraffin-oil mixtures had little or no value in scald control. As already noted, the beeswax-paraffin-oil mixtures not only had a low oil content but also were applied to the apples in much smaller quantities than the other materials. The poor scald control secured with these mixtures and the contrasts in control with the heavy and light applications of oil indicate a correlation between quantity of oil applied and degree of efficiency in scald control.

NATURE OF SCALD CONTROL

Investigations in regard to the general nature of apple scald were reported in an earlier publication.[3] It was established by experimental data that in so far as the usual storage conditions were concerned scald was the result of tight packages and tight storing and that the disease could be prevented by free air movement over the apples. It was shown that while tight storage naturally resulted in a decrease in the oxygen

[3] Brooks, Charles, Cooley J. S., and Fisher, D. F. op. cit.

and an increase in the carbon dioxid present in the storage air, these conditions were not responsible for the development of scald and, in fact, that increases in the carbon-dioxid content of the air actually tended to hold the disease in check. Experiments on humidity indicated that the benefits from air currents probably could not be attributed to their drying effect. Withered apples usually scalded less than crisp ones but apparently because of the aeration that accompanied the drying rather than from the drying itself. Apples stored in the air that was saturated with moisture but constantly stirred did not develop scald while similar apples in dry, stagnant air became badly scalded. The negative results along the above lines finally led to testing the effects of the odorous products of the apple. It was found that typical scald conditions could be produced by exposing the apples to odorous substances similar to those given off by the apples and that various odor-absorbing materials such as fats and oils could be used as scald preventives. These facts gave the foundation for the development of the oiled wrapper.

The data of the present paper furnish additional evidence in regard to the factors involved in scald control. That the question of humidity is secondary or negligible is indicated by the fact that the tin foil and glassine wrappers (see Table I) had little or no effect upon scald, by the fact that the paraffin wrappers had less than half the efficiency of the mineral oil wrappers, and also by the fact that the oiled and waxed apples although still oily and sticky at the time of removal from storage were not protected from scald to anything like the degree that prevailed with the apples held in oiled wrappers. In these various tests there was apparently no correlation between moisture control and scald control.

It was stated above that increases in the carbon-dioxid content of the storage air resulted in a decrease in apple scald. The oiled wrappers and the direct oil and wax treatments tend to restrict the free air movement between the apple tissues and the outside air and would favor the accumulation of the carbon-dioxid of respiration in the air within and immediately surrounding the apple. It would therefore seem possible that their value in scald control might be due to this restriction of gaseous exchange. This can not be true, however, in so far as the direct physical protection of the oiled wrapper is concerned, for if this were the case the glassine wrapper, which is made of practically air-tight paper, should give better scald control than the oiled wrapper, the paraffin wrapper should give practically as good control, and double and triple wrapped apples should have greater freedom from scald than single wrapped ones, all of which conditions are contrary to the facts. If the oiled wrapper is of value on account of physical barriers set up, it must be through the coating of oil it deposits on the apple.

With the oil and wax treatments of the apple and with the film of oil that passes over from the wrapper to the apple there is the possibility both of restriction in gaseous exchange and of more direct physiological effects upon the skin of the apple. That a definite physiological effect is produced is evidenced by the fact that the development of yellow in the ground color of the apple is delayed by both methods of treatment and approximately in proportion to the amount of oil that is deposited on the apple. It would seem probable that any agency that had a checking or inhibiting effect upon the skin of the apple might at the same time be responsible for a reduction in scald, but it does not seem possible to fully explain the scald control secured with the oiled wrapper on this

basis. The scald control secured with the direct applications has been approximately in proportion to the amount of oil used and in proportion to the inhibition of coloring, but the scald control secured with the oiled wrapper has been entirly out of proportion to the amount of oil deposited on the apples and out of proportion to the inhibition of color development in the skin. The direct application of 0.017 gm. of oil per apple has reduced scald from 40.5 per cent to 14.7 per cent (see Table VIII and discussion), and the direct application 0.06 gm. per apple has reduced the disease to 9.1 per cent; while the use of oiled wrappers with a deposit of less than 0.0211 gm. of oil per apple (see Table III and discussion) has reduced scald to 0.5 per cent. The results of the various investigations on scald have shown that the elimination of the last 10 or 15 per cent of the disease is far more difficult than similar reductions from higher percentages; and it seems impossible to explain the extreme efficiency of the oiled wrapper on the basis of the small deposit of oil on the apple. The evidence at hand seems to justify the conclusion that the inhibition of coloring in the skin of the apple is due to the oil actually deposited on it, but that the scald control is determined by the total oil lying in close proximity to the apple but not necessarily deposited on it.

This theory of scald control receives further support from the fact that the disease has been greatly reduced on apples that were unwrapped or in unoiled wrappers, but adjacent to apples in oiled wrappers, and slightly reduced on similar apples that were two or more layers distant from the oiled wrappers (Table VI), and also by the fact that apples with an unoiled wrapper inside the oiled one and with apparently no deposit of oil on the apples have had but little more scald than those with the oiled wrapper in direct contact with the skin of the apple.

CRITICAL PERIODS IN THE DEVELOPMENT OF SCALD

The oiled wrapper has furnished a convenient means of determining the period in the storage season in which the different varieties of apples need the greatest protection against scald. Table IX shows the results obtained by applying the oiled wrappers at different times; in some cases at picking time and in others several weeks after the apples had been placed in storage.

The results show that it is not essential to scald control that the wrappers applied at picking time should remain on the fruit throughout the storage season. In one experiment Rome Beauty apples remained free from scald when the oiled wrappers were removed at the end of 4 weeks of storage, and in another they scalded when they were removed at the end of 5 weeks but not when removed at the end of 10 weeks. Stayman Winesap scalded when the oiled wrappers were removed at the end of 6 weeks, but remained free from scald when removed at the end of 9 weeks. Winesap remained free from scald when the wrappers were removed at the end of 8 weeks, while Grimes Golden scalded badly when the wrappers were removed at the end of 9 weeks.

Oiled wrappers applied during the first month of storage gave as complete scald control on all varieties as those applied at picking time; those applied at the end of 8 weeks gave only partial control on Arkansas, York Imperial, and Stayman Winesap, while those applied at the end of 12 weeks of storage gave complete control on Rome Beauty and Winesap.

TABLE IX.—*Critical periods in the development of apple scald as shown by the results from oiled wrappers applied at different times in the storage season*

Description of apples and wrappers.	Wrappers applied.	Degree of scald manifest after storage.
Grimes Golden, Rockville, Md.; picked Sept. 3, 1920; notes taken Jan. 8, 1921:		*Per cent.*
Unoiled wrappers	At picking time	66
Mineral oil wrapper No. 3	do	0
Do	Nov. 3, 1920	0
Do	Nov. 23, 1920	2
Do	Dec. 10, 1920	54
Grimes Golden, Wenatchee, Wash.; picked Sept. 20, 1920; notes taken Feb. 12, 1921:		
Unoiled wrapper	At picking time	25
Mineral oil wrapper No. 3a	do	0
From unoiled wrapper applied at picking time to No. 3a	Oct. 27, 1920	0
Do	Nov. 11, 1920	0
Do	Nov. 26, 1920	1
Grimes Golden, Wenatchee, Wash.; picked Sept. 19, 1921; notes taken Mar. 1, 1922:		
Unoiled wrapper	At picking time	31
Mineral oil wrapper No. 4b	do	0
From unoiled wrapper applied at picking time to No. 4b	Oct. 3, 1921	0
Do	Oct. 21, 1921	0
Do	Nov. 21, 1921	0
From mineral oil wrapper No. 4b applied at picking time to unoiled wrappers	Oct. 3, 1921	24
Do	Oct. 21, 1921	17
Do	Nov. 21, 1921	24
York Imperial, Arlington, Va.; picked Sept. 27, 1920; notes taken Apr. 3, 1921:		
Unoiled wrapper	At picking time	32
Mineral oil wrapper No. 3	do	0
Do	Nov. 3, 1920	5
Do	Nov. 23, 1920	18
Arkansas (Mammoth Black Twig), Winchester, Va.; picked Oct. 18, 1920; notes taken Jan. 24, 1921:		
Unwrapped		42
Mineral oil wrapper No. 3	Nov. 11, 1920	2
Do	Dec. 15, 1920	22
Do	Dec. 28, 1920	35
Mineral oil wrapper No. 3a	Nov. 11, 1920	3
Do	Dec. 15, 1920	23
Rome Beauty, Wenatchee, Wash.; picked Oct. 20, 1920; notes taken May 18, 1921:		
Unoiled wrapper	At picking time	30
Mineral oil wrapper No. 3a	do	0
From unoiled wrapper applied at picking time to No. 3a	Nov. 20, 1920	0
Do	Dec. 20, 1920	0
Do	Jan. 21, 1921	0
Do	Feb. 25, 1921	11
From mineral oil wrapper No. 3a applied at picking time to unoiled wrapper	Nov. 20, 1920	0
Do	Dec. 20, 1920	0
Do	Jan. 21, 1921	0
Do	Feb. 25, 1921	0
Rome Beauty, Wenatchee, Wash., picked Oct. 27, 1921; notes taken Apr. 22, 1922:		
Unoiled wrapper	At picking time	22
Mineral oil wrapper No. 4a	do	0

TABLE IX.—*Critical periods in the development of apple scald as shown by results from oiled wrappers applied at different times in storage season*—Continued

Description of apples and wrappers.	Wrappers applied.	Degree of scald manifest after storage.
Rome Beauty, Wenatchee, Wash., etc.—Continued.		
Unoiled wrapper applied at picking time and removed and replaced	Dec. 1, 1921	*Per cent.* 24
Do	Jan. 2, 1922	15
From unoiled wrapper applied at picking time to No. 4a	Dec. 1, 1921	0
Do	Jan. 2, 1922	2
From mineral oil wrapper No. 4a applied at picking time to unoiled wrapper	Dec. 1, 1921	7
Do	Jan. 2, 1922	0
Stayman Winesap, Wenatchee, Wash.; picked Oct. 9, 1920; notes taken May 23, 1921:		
Unoiled wrapper	At picking time	16
Mineral oil wrapper No. 3a	do	0
From unoiled wrapper applied at picking time to No. 3a	Nov. 20, 1920	0
Do	Dec. 8, 1920	11
Do	Jan. 10, 1921	3
Do	Feb. 25, 1921	7
From mineral oil wrapper No. 3a applied at picking time to unoiled wrapper	Nov. 20, 1920	3
Do	Dec. 8, 1920	0
Do	Jan. 10, 1921	0
Do	Feb. 25, 1921	0
Winesap, Wenatchee, Wash.; picked Oct. 25, 1920; notes taken June 20, 1921:		
Unoiled wrapper	At picking time	9
Mineral oil wrapper No. 3a	do	0
From unoiled wrapper applied at picking time to No. 3a	Dec. 20, 1920	0
Do	Jan. 21, 1921	1
Do	Feb. 25, 1921	2
Do	Apr. 4, 1921	4
From mineral oil wrapper No. 3a applied at picking time to unoiled wrapper	Dec. 20, 1920	0
Do	Jan. 21, 1921	0
Do	Feb. 25, 1921	0
Do	Apr. 4, 1921	0

All of the repacking was done in the cold storage rooms and it was not believed that the apples received enough aeration during the exchange of wrappers to materially influence the development of scald, but this point was definitely tested with one lot of Rome Beauty. The unoiled wrappers were removed and the apples repacked in the same wrappers without securing scald control, while similar apples repacked in oiled wrappers were free from scald at the end of the storage period.

The results of the experiments reported in Table IX have a practical value in showing that where apples are stored in orchard boxes and packed out later, the oiled wrappers can still be used to advantage in scald control. They are of general pathological interest because of the light they throw on the cumulative nature of a physiological disease, and they are in agreement with the experiments on aeration reported in earlier publications in showing that the development of scald can be divided into several fairly distinct periods or stages.

The first period in the development of apple scald begins with the picking of the fruit and, with the more susceptible varieties, ends with

the sixth or eighth week of storage. During this time the scald-producing agencies are apparently most active, yet up to the end of the period it is possible to largely or entirely overcome any accumulated tendencies to the disease by wrapping the apples in oiled paper or by airing them out in a warm room. The second stage in the development of the disease extends over a 5 to 8 week period following the first. Preventive measures have now become of little or no avail. The apples are doomed to scald if given sufficient time, yet if removed from storage before the end of the period they do not show scald even upon warming. The third stage or period covers the remainder of the time the apples are in storage. They have now become latently or potentially scalded. Certain skin cells are practically dead, yet will remain green and appear practically normal if not exposed to warm air. The fourth stage includes the life of the scalded apples after removal from storage. The affected skin turns brown and completes its death processes.

SUMMARY

The results are reported on 67 different apple storage experiments carried out under commercial storage conditions.

Apples packed in the usual unoiled wrappers have had practically the same degree of scald as those that were unwrapped.

Paraffin wrappers have caused considerable reduction in the prevalence of scald, but have proved far inferior to oiled wrappers.

In 63 of the 67 tests the oiled wrappers have either entirely prevented the development of scald or reduced it to a degree that made it negligible from the commercial standpoint. The apples in oiled wrappers have shown but little if any delay in coloring and have been entirely normal in taste and appearance.

Wrappers carrying less than 15 per cent of oil have been less efficient in scald control than those carrying 15 per cent (about 0.28 gm. per wrapper) or more of oil.

Seven different mineral oils have been tested in the oiled wrappers and all have been efficient in scald control.

Oiled blotter material scattered through the barrel package has reduced scald to about one-third the amount found in the untreated barrels.

Oils and mixtures of oils and waxes applied to the skin of the apple have given rather erratic results in scald control, the efficiency of the treatment usually varying with the amount of oil applied. The apples have usually had a greasy appearance and an abnormal greenness, sometimes accompanied by a lack of flavor and a general condition of the fruit similar to that resulting from storage in high percentages of carbon dioxid.

Various oil determinations are reported, giving the amount of oil in the fresh wrappers and in the used ones, the amount taken up by box liners; and the amount taken up by unoiled wrappers applied to the apples inside the oiled ones.

The conclusion is drawn that the checking of the changes from green to yellow in the skin of the apple is due to the oil actually deposited on the apple, and that the extent of the scald control is largely determined by the amount of oil in close proximity to the skin of the apple but not necessarily deposited on it.

Four stages, or periods, are recognized in the development of scald each bearing a different relation to remedial measures.

INFLUENCE OF TEMPERATURE AND INITIAL WEIGHT OF SEEDS UPON THE GROWTH-RATE OF PHASEOLUS VULGARIS SEEDLINGS[1]

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INTRODUCTION

In the recent extensive publications upon quantitative aspects of growth of plants, the present state of this work is adequately summarized. The study reported in this paper was conducted in an attempt to discover, first, the direct influence of temperature upon the growth curves of plants when as many environmental factors as possible were controlled, and, second, to determine the influence of initial weight of seeds upon the rate of growth of the plants under such conditions.

EXPERIMENTAL RESULTS

A large number of seeds of *Phaseolus vulgaris* (beans) were selected according to their initial weights. Those designated as "small seeds" weighed (air dry) from 6.92 to 7.23 gm. per 50 seeds, and those designated as "large seeds" weighed from 13.52 to 14.41 gm. per 50 seeds. The seeds were placed on top of greenhouse soil kept at a moisture content of 60 per cent of the water-holding capacity. As soon as the seeds germinated they were covered with a thin layer of soil and placed in dark incubators, subject to accurate humidity control (60 per cent relative humidity), and kept at definite temperatures of 5°, 10°, 15°, and 20° C. The elongation of the shoots and of each internode was measured daily in millimeters at approximately the same hour, care being taken to start each time with the same individuals. Measurements were taken until the seedlings collapsed or the plants stopped growing. The greatest height reached by any group of seedlings was nearly 28 cm. (20° C.), while the group of seedlings grown at 5° C. attained a height of less than 2 cm. The average readings of from 20 to 50 individuals were fitted to Robertson's[3] autocatalytic formula:

$$\log.\frac{x}{a-x} = K\ (t-t_1).$$

In this equation a is the final size of the organism; x is the size of the organism at time t; and t_1 is the time at which the organism has reached half its final size, or when $x = \frac{a}{2}$; and K is a constant. Robertson's[4] tables for the computation of curves of autocatalysis were used to check the calculations.

[1] Accepted for publication November 1, 1923. This is paper No. 145 of the Journal Series, New Jersey Agricultural Experiment Station, Department of Soil Chemistry and Bacteriology.

[2] The writer is indebted to Earl S. Harris, formerly junior chemist, New Jersey Agricultural Experiment Station, for the help rendered in calculating the results herein reported.

[3] ROBERTSON, T. Brailsford. TABLES FOR THE COMPUTATION OF CURVES OF AUTOCATALYSIS, WITH ESPECIAL REFERENCE TO CURVES OF GROWTH. *In* Univ. Calif. Pub. Physiol., v. 4, p. 211–228. 1915.

[4] ROBERTSON, T. Brailsford. FURTHER REMARKS ON THE NORMAL RATE OF GROWTH OF AN INDIVIDUAL AND ITS BIOCHEMICAL SIGNIFICANCE. *In* Arch. Entwicklungsmech. Organ., Bd. 26, p. 108–118. 1908.

Journal of Agricultural Research, Washington, D. C.

Vol. XXVI, No. 11
Dec. 15, 1923
Key No. N. J. -10

Figure 1 shows the observed values, together with the calculated curve for the shoots of large-sized beans (13.71 gm. per 50 seeds) grown at a constant temperature of 15° C. It can be seen that the agreement between observed and calculated values is good except for the first few points. The agreements between the observed and calculated values for the other sets of curves were as good as in the above example. In order to avoid the printing of tables, the individual figures observed are placed on file for examination in the office of the New Jersey Agricultural Experiment Station at New Brunswick, N. J.

The fitted curves for the data secured for the different sizes of seeds and at different temperatures are presented in figure 2. The total averages for the seeds of different sizes grown at 5° and at 10° C. are given in two curves, while the data obtained from small and from large

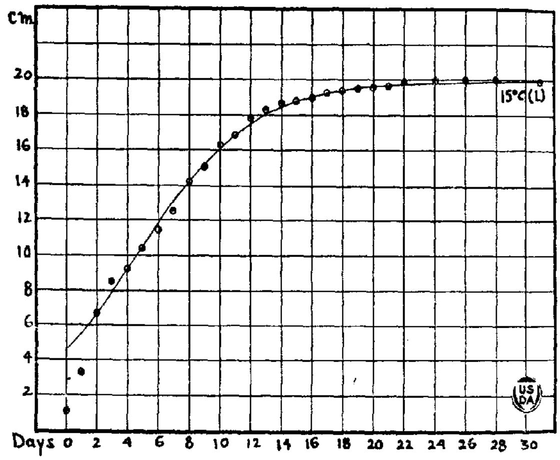

FIG. 1.—Growth-rate of shoots of *Phaseolus vulgaris* kept at constant temperature of 15° C. The curve represents the fitted graph and circles represent the observed lengths.

seeds grown at 15° and at 20° are calculated separately and presented in different curves.

It is apparent that almost no growth occurred at 5° C. The average growth at all sizes of seeds grown at 10° C. is about the same as the growth produced by small seeds grown at 15° C. The curves for plants grown at 15° and at 20° C. show strikingly that the advantage is in favor of the plants grown from the heavier seeds as compared with those from the lighter seeds. This advantage is not only maintained throughout the growth period but is also augmented as time progresses. It must be kept in mind that the plants were grown in darkness and stopped growing as soon as the reserve material in the seeds was used up. The decrease in food material caused the plants to grow more and more slowly, hence the flattening of the curves.

These results show that, photosynthesis aside, the large store of food in the larger seeds probably makes it possible for the plant to which they gave rise to obtain a relatively better start.

The influence of temperature upon the growth curves is very pronounced, especially in the case of large seeds. This phenomenon might

be expected, since the initial amount of reserve material seems to determine the total growth product, while the temperature acts as an accelerating factor. In order to illustrate the relation between seed-weight, temperature, and growth-rate, we may consider the time required to obtain a growth of 140 mm. for the large and for the small seeds, respectively: At 10° C., large and small seeds require 9.8 days; at 15°, large seeds, 7.8 days; small seeds, 8.8 days; at 20°, large seeds 3.1 days; small seeds, 8.5 days. It can be seen that in the case of large seeds a normal temperature coefficient exists, while in the case of small seeds the temperature coefficient is abnormally small. This would seem to suggest that the amount of food stored in the seeds is of major importance for early growth.

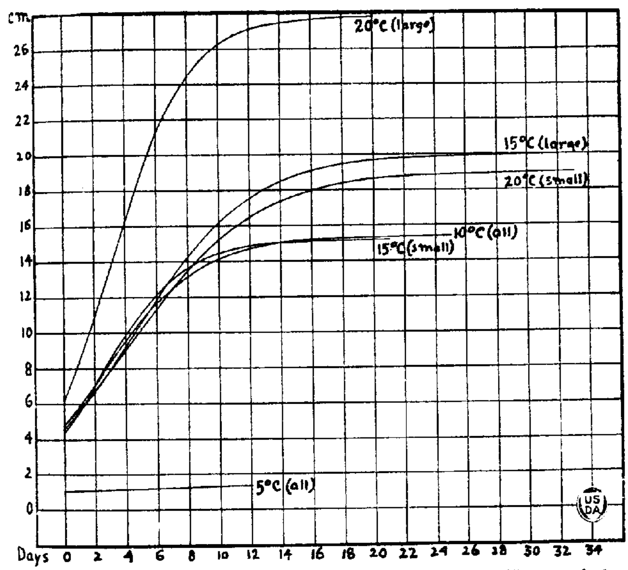

FIG. 2.—Growth rate of shoots of beans kept at different constant temperatures. The curves for beans, grown at 15° and 20° C. represent two different groups of seeds with different initial seed weights.

SUMMARY

Bean seeds of different sizes (weights) were selected and grown in darkness in greenhouse soil with 60 per cent of its water-holding capacity, constant relative air humidity (60 per cent), and at constant temperatures of 5°, 10°, 15°, and 20° C., until the seedlings stopped growing or collapsed. Robertson's equation, considering growth as an autocatalytic chemical reaction, was applied.

Under these uniform conditions plants of seeds of a heavier weight show a decided advantage over plantlets from seeds of light initial weight.

Temperature acting as an accelerating factor increases the advantage of plants grown from seeds with a greater initial weight.

SOME FACTORS WHICH INFLUENCE THE FEATHERING OF CREAM IN COFFEE[1]

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PLAN OF EXPERIMENTS

Feathering is the flaking or curdling of cream in coffee. This is sometimes troublesome to milk dealers because customers assume that it indicates sourness; and because, although sweet cream when it feathers does not produce a sour taste in the coffee, yet it gives an unpleasing appearance. It is known that sour cream will feather when added to hot coffee, but at times cream that is sweet to the taste will do likewise. From this it may be concluded that there must be factors other than high acidity which affect or influence feathering. With this in mind a number of factors were studied as follows:

Acidity of coffee made by different methods—boiled, percolated, drip.

Use of coffees of different grades—high, medium, low.

Method of mixing cream and coffee—

(*a*) Adding cream to coffee without sugar.

(*b*) Adding cream to coffee and sugar.

(*c*) Adding coffee to cream without sugar.

(*d*) Adding coffee to cream and sugar.

Age of cream.

Kind of cream—percentage of butterfat, and whether raw, pasteurized, homogenized, or frozen.

The acidity of the cream was the basic factor for determining the effect which these various other factors had on the feathering of the cream. The acidity was determined as lactic acid by titrating with N/20 NaOH, using phenolphthalein as an indicator. The conclusions are based on results obtained from a total of about 900 different tests.

ACIDITY OF COFFEE

Three different methods of making coffee were tried—boiling, percolating, and dripping.

Boiled.—The coffee was medium ground, 50 grams to 500 cc. of distilled water, boiled for five minutes, filtered, cooled, and made up to 500 cc.

Percolated.—The coffee was medium ground, 50 grams to 500 cc. distilled water, percolated for five minutes, filtered, cooled, and made up to 500 cc.

French drip.—Pulverized coffee, 50 grams to 500 cc. of boiling distilled water poured through the coffee once, filtered, cooled, and made up to 500 cc.

[1] Accepted for publication Nov. 19, 1923.

[2] Credit is due Geo. B. Taylor, former market milk specialist with this division, for preliminary work in these experiments.

The acidity of the coffees made by these various methods, using brom-thymol blue as indicator, is shown in the following table:

TABLE I.—*Acidity of coffee made by various methods*

Method.	N/10NaOH required to neutralize 100 cc. of coffee.	Hydrogen-ion concentration.
	Cc.	P_H
Boiled	11.0	4.92
Percolated	11.5	4.91
French drip	12.0	4.92

There was practically no difference in the acidity of the coffee made by these methods. Because of this fact it was considered unnecessary to run cream tests on coffee made by all three methods. The French drip method was selected for all the experiments. Fifty grams of pulverized coffee were used to 1,000 cc. of water.

GRADE OF COFFEE

Three different grades of coffee of known quality—high, medium, and low—were obtained through the New York office of the Bureau of Chemistry. These three grades and a special brand of coffee purchased on the market were used in experiments on the effect of different grades of coffee on feathering.

The titratable acidity of the different grades, using brom-thymol blue as indicator, was practically the same for all and was as follows:

TABLE II.—*Acidity of coffee of different grades*

Grade.	N/20 NaOH required to neutralize 100 cc. of coffee.
	Cc.
High	12.0
Medium	12.0
Low	12.5
Special brand	12.5

There was no noticeable difference in the effect of these various grades of coffee on the feathering of the cream, as shown in a total of 120 tests run on each coffee, in which the following grades of cream were used: Raw cream testing 20 per cent butterfat, pasteurized cream testing 20 per cent, pasteurized and homogenized cream testing 20 per cent, and raw cream testing 35 per cent.

METHOD OF MIXING CREAM AND COFFEE

In the remaining experiments the special brand of coffee was used. The average temperature of the coffee at the actual time of mixing the cream with it was about 95° C. Each experiment consisted of—

(*a*) Adding cream to coffee without sugar.
(*b*) Adding cream to coffee and sugar.
(*c*) Adding coffee to cream without sugar.
(*d*) Adding coffee to cream and sugar.

Cream always feathered at a lower acidity in method (*d*)—when the coffee was added to the cream and sugar. (See Tables III to VIII.) This may be attributed to the fact that the sugar in dissolving used moisture from the cream and in so doing precipitated some of the casein present, causing feathering when the hot coffee was added. If the sugar was moistened with a little water before adding the cream, or the sugar was added to the coffee either before or after adding the cream, then the sugar had no effect on the feathering.

In practically all the tests, method (*c*)—adding the coffee to the cream without sugar—had the least effect on the feathering, i. e., the cream did not feather at so low an acidity when the coffee was added to the cream without sugar. Sugar may be added afterwards without affecting the feathering. (See Tables III to VIII.)

AGE OF CREAM

The effect of age of cream on feathering was determined by aging cream at low temperatures (1° to 2° C.) so as to keep acidity increase at a minimum. Aging cream for 7 to 10 days by this method had no effect on the feathering.

KIND OF CREAM

The richness of the cream had very little effect on the feathering. The richer creams, i. e., those containing a higher percentage of butterfat, feathered at a slightly lower acidity. This was undoubtedly due to the fact that the acidity in the richer creams was more nearly true acid than in the case of the less rich creams, containing more solids not fat, which would affect the titratable acidity. (See Tables III and IV.)

The acidity of all the cream was determined by titrating 10 cc. of the cream with N/20 NaOH, using phenolphthalein as indicator.

Pasteurizing had but slight effect on the feathering. Comparative tests of raw and pasteurized creams showed that the pasteurized creams feathered at a slightly lower acidity than the same cream not pasteurized. (See Tables III, V, and VI.)

Homogenizing greatly affects the feathering of cream. Homogenized cream feathered at a decidedly lower acidity than any that was not homogenized. There were considerable variations in the percentage of acidity at which the homogenized cream feathered, due undoubtedly to the fact that the samples were purchased from different dealers, who probably were using different homogenizing pressures. No information concerning the pressures used was obtained. (See Table VII.) Comparative tests, using different pressures, showed that the higher the pressure at which the cream was homogenized, the lower the acidity at which it feathered. (See Table VIII.)

Freezing the cream had apparently no effect on the feathering; a heavy oily layer would form on the coffee, however.

RESULTS OF EXPERIMENTS

In Tables III to VIII, showing the results of the experimental work, the four methods of mixing the cream and coffee are described as follows: *a* represents adding cream to coffee without sugar; *b* represents adding

cream to coffee and sugar; *c* represents adding coffee to cream without sugar; *d* represents adding coffee to cream and sugar.

TABLE III.—*Results of composite tests of raw cream testing 18 and 20 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
0.225 per cent	No feathering	No feathering	No feathering	Feathering.
0. 29 per cent	do	do	do	Do.
0.295 per cent	Trace	Trace	do	Do.
0.315 per cent	Feathering	Feathering	Trace	Do.
0.32 per cent	do	do	Feathering	Do.

TABLE IV.—*Results of composite tests of raw cream testing 30 and 35 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
0.22 per cent	No feathering	No feathering	No feathering	Feathering.
0.26 per cent	do	do	do	Do.
0. 30 per cent	Feathering	Feathering	Trace	Do.

TABLE V.—*Results of composite tests of pasteurized cream testing 20 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
0.225 per cent	No feathering	No feathering	No feathering	Feathering.
0.26 per cent	do	do	do	Do.
0.295 per cent	Feathering	Feathering	Trace	Do.

TABLE VI.—*Comparative tests of raw and pasteurized cream testing 30 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
Raw cream:				
0.23 per cent	No feathering	No feathering	No feathering	Feathering.
0.26 per cent	do	do	do	Do.
0.30 per cent	Feathering	Feathering	Feathering	Do.
Pasteurized cream:				
0.22 per cent	No feathering	No feathering	No feathering	Do.
0.24 per cent	do	do	do	Do.
0.275 per cent	Feathering	Feathering	Trace	Do.
0.295 per cent	do	do	do	Do.

TABLE VII.—*Composite tests of homogenized and pasteurized cream testing 20 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
0.125 per cent...	No feathering...	No feathering...	No feathering...	Trace.
0.14 to 0.16 per cent.	Trace..........	Trace..........	.....do.........	Feathering.
0.155 to 0.185 per cent.	Feathering......	Feathering......	Trace..........	Do.
0.165 to 0.22 per cent.	.....do.........	.....do.........	Feathering......	Do.

TABLE VIII.—*Effect of homogenizing pressure on feathering of raw cream testing 30 per cent butterfat*

Acidity of cream.	Method of mixing cream and coffee.			
	a	*b*	*c*	*d*
1,000 pounds pressure:				
0.135 per cent.	No feathering[a]..	No feathering...	No feathering...	No feathering.
0.145 per cent.	.....do.........	.....do.........	.....do.........	Do.
0.185 per cent.	Feathering......	Feathering......	Trace..........	Feathering.
2,000 pounds pressure:				
0.125 per cent.	No feathering...	No feathering...	No feathering...	No feathering.
0.135 per cent.	.....do.........	.....do.........	.....do.........	Feathering.
0.170 per cent.	Feathering......	Feathering......	Feathering......	Do.
3,000 pounds pressure:				
0.135 per cent.	Trace..........	No feathering...	No feathering...	Do.
0.145 per cent.	.....do.........	Trace..........	.....do.........	Do.
0.175 per cent.	Feathering......	Feathering......	Feathering......	Do.
,000 pounds pressure:				
0.135 per cent.	Trace..........	Trace..........	No feathering...	Do.
0.145 per cent.	Feathering......	Feathering......	.....do.........	Do.
0.180 per cent.	.....do.........	.....do.........	Feathering......	Do.

[a] There was no feathering up to 0.190 per cent acid on a sample of the same cream not homogenized.

SUMMARY

In determining the effect of the various factors on the feathering of cream in coffee, the acidity of the cream was taken as the basic factor, because it was present in all cases. It was also the factor having the greatest influence on feathering. Cream having an acidity of three-tenths of 1 per cent tastes sour to most people and will almost invariably feather when added to hot coffee.

The average temperature of the coffee at the time of mixing it with the cream was about 95° C.

The acidity of the coffee made by different processes, namely, boiled, percolated, and dripped, was practically identical. The hydrogen-ion determinations were respectively as follows: P_H 4.92, 4.91 and 4.92. This excluded the method of preparation as having any effect on feathering.

The acidity of coffee made by the drip method from high, medium, and low grades of known quality, and from a special brand of unknown quality but supposedly high grade, was practically the same. There was no noticeable difference in the effect of the various grades of coffee on the feathering of the cream.

Each experiment consisted of—

(*a*) Adding cream to coffee without sugar.
(*b*) Adding cream to coffee and sugar.
(*c*) Adding coffee to cream without sugar.
(*d*) Adding coffee to cream and sugar.

Of these four factors, adding the coffee to the cream and sugar had the greatest effect on the feathering; in other words, the cream feathered at a much lower acidity in (*d*) than it did in either (*a*), (*b*), or (*c*). Adding the coffee to the cream without sugar, (*c*), had the least effect on the feathering, although the advantage as compared with (*a*) and (*b*) was very slight.

Aging cream for from 7 to 10 days at a low temperature (1° or 2° C.) so as to keep acidity increase at a minimum, had no effect on the feathering.

The richness of the cream had very little effect on the feathering, though the richer cream (higher in percentage of butterfat) feathered at a slightly lower acidity. This was undoubtedly due to the fact that the titratable acidity in the richer cream was more nearly true acid.

Pasteurizing had but little effect on the feathering; however, there was a tendency for pasteurized cream to feather at a slightly lower acidity than the same cream not pasteurized.

Homogenization greatly affected the feathering of cream, causing it to feather at a decidedly lower acidity than any of the creams not homogenized. The greater the homogenizing pressure used, the lower the acidity at which the cream feathered.

Freezing the cream had no effect on feathering. A heavy, oily layer always appeared on the coffee, however, when cream that had been frozen was added.

The main factors causing feathering of cream in coffee are: High acidity; homogenization; adding hot coffee to cream and sugar. Acidity and homogenization are chiefly commercial problems. It is well to homogenize only cream of very low acidity if it is to be used in coffee and to keep the homogenizing pressure as low as possible. Adding hot coffee to cream and sugar is a household and restaurant problem. It is well not to mix the cream and sugar before adding the hot coffee.

BIOLOGY OF THE FALSE WIREWORM ELEODES SUTURALIS[1] SAY[2]

By J. S. WADE,[3] *Entomologist, Cereal and Forage Insect Investigations*, and R. A. ST. GEORGE, *Assistant Entomologist, Forest Insect Investigations, Bureau of Entomology, United States Department of Agriculture*

INTRODUCTION

The false wireworm *Eleodes suturalis* Say is now a serious menace to the production of wheat and other small grains in both irrigated and nonirrigated districts in some of the more recently settled, semiarid regions of the Middle West. It is an impressive illustration of a truth repeatedly emphasized by the late Prof. F. M. Webster (*33, p. 72*)[4], namely, that insects formerly supposed to be of little or no economic importance have frequently—

come suddenly into prominence and become immensely destructive to crops.

Its principal damage is caused in the fall by the larvæ feeding upon the recently sown wheat grain and its sprouts, thus retarding or preventing the formation and growth of the young plant. It also injures or destroys growing wheat in the spring.

The comparatively recent development of *Eleodes suturalis* as a pest is due largely to artificial change in its environment and food plants. Large areas formerly devoted to grazing have been brought under cultivation, and this has diminished or almost eliminated a number of the native food plants and has caused the insect to attack some of the crops now grown in their place. This change of food plants and possibly better facilities for hibernation in the cultivated fields have resulted in a steady increase in abundance of the pest.

Although, owing to the partial control effected by meteorological conditions and parasites in each infested locality, the more destructive outbreaks of this false wireworm have occurred only at irregular intervals, yet the activities of the pest have been reported with increasing frequency each year since 1910 in widely separated districts within its range, indicating that the species is likely to become increasingly injurious in future years.

The territory under discussion comprises more especially the semiarid sections of western Texas, New Mexico, Colorado, Oklahoma, Kansas, Nebraska, and the Dakotas, west of the ninety-seventh meridian, and the life-history notes are based upon studies made in the years from 1914 to 1917, inclusive, in the latitude of southern Kansas, the deductions therefrom being based upon behavior of the specimens under observation.

HISTORY

This insect belongs to the extensive coleopterous family Tenebrionidae, and to a group popularly known by the expressive term of "stink-

[1] Order Coleoptera, family Tenebrionidae.
[2] Accepted for publication, Nov. 1, 1923.
[3] The writer wishes to acknowledge his indebtedness to the late Prof. F. M. Webster, and to W. R. Walton, E. G. Kelly, and Dr. E. A. Schwarz, all of the Bureau of Entomology, for helpful advice and for much valuable information.
[4] Reference is made by number (italic) to "Literature cited," p. 565-566.

Journal of Agricultural Research, Washington, D. C.
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Vol. XXXVI, No. 11
Dec. 15, 1923
Key No. K-120

bugs." It was first authentically described under the name of *Blaps suturalis* by Thos. Say (*23, p. 257*) in 1824. This description was republished (*24, p. 30, pl. 16, fig. 2*) in the same year and subsequently appeared under the same name in Say's Collected Works (*25, p. 30, pl. 16, fig. 2*) in 1859. The insect was removed from the genus Blaps in 1829 and placed in the genus Eleodes by Eschscholtz (*7, p. 10*), who indicated the generic structural characters of the insect upon which the change was based. Le Conte (*16, p. 182–183*) in 1858, following his description of *Eleodes suturalis* var. *texana*, emphasized that the species discussed is—

Allied to *Eleodes suturalis*, but much larger and narrower, with the sides of the thorax and elytra still more strongly margined.

It is interesting to note that the genus Eleodes by that time embraced a large number of species of very varied form, and those described by Le Conte served yet further to illustrate the protean character of the genus. Le Conte (*17, p. 121–122, pl. 12, fig. 5*) in 1859, in further discussion of *Eleodes suturalis* var. *texana*, reviewed the description already published and directed attention to the exceedingly great variations of the species within the genus. Lacordaire (*15, p. 148–149, pl. 51, fig. 3*) in 1859 merely directed attention to the more commonly known distinguishing characters between this and related species. Horn (*11, p. 306*) in 1870, in his monographic revision of the Tenebrionidae, separated *Eleodes suturalis* from *E. obscura* and *E. acuta* by the flat or concave thorax, and further separated *E. suturalis* and *E. texana* according to rounded sides of the elytra in the former and the parallel sides of the elytra in the latter. He added further concerning *E. suturalis* that—

The general form of this species agrees with the two already mentioned [*Eleodes obscura* and *E. acuta*], differing, however, in having both the thorax and elytra with a very acute margin, generally slightly reflexed in the latter, always so in the former, so that the dorsum appears either flattened or concave in accordance with the degree to which they are upturned. The sides of the elytra are rounded, never parallel, the dorsum is always flat. The anterior femora are not very acutely toothed, frequently merely sinuate . . . Many specimens have a broad red band along the suture of the elytra.

Concerning *Eleodes texana* Lec., Horn directed attention to the fact that it, too, was acutely margined. In comparing it with *E. suturalis* he noted that the thoracic margin is much wider and more reflexed, the thorax broader, the sides more strongly rounded, the apex deeply emarginate with acute angles, and the base trisinuate and with acute angles. The elytra are more acutely margined than in *E. suturalis*, the dorsum slightly concave, longer and more parallel and in the males slightly produced, their surface also feebly sulcate with striæ of coarse, closely placed punctures. The anterior femora of the male are armed with a rather short acute tooth. Horn (*12, p. 34*) in 1874, after making further study of the various species from more widely separated localities in Texas, became—

convinced that this species [*E. texana*] is merely a large variety of *E. suturalis* Say.

Casey (*4, p. 394*) in 1890, in discussion of generic differences between Blaps and Eleodes, made comparison of the form of the mentum between *Blaps mortisaga* and *Eleodes suturalis*, but indicated that the facts relative thereto were of doubtful taxonomic importance. Blaisdell (*3, p. 199–205, pl. 1, fig. 14, 19, 23*) in 1909, in his very full discussion of the characters of the typical form of *E. suturalis* and of the variety *E. texana*, left little to be desired. He reviewed the salient type characters of *E.*

suturalis as given by Say. These are as follows: Reddish brown along suture. Thorax with edge deeply concave in front, lateral margin dilated and reflected; anterior angles with a small escurved point. Elytra scabrous, grooved, lateral edge reflected, slightly elevated and acute. He also reviewed the salient type characters as given by Le Conte of *E. suturalis* var. *texana*. These are as follows: Thorax with the disk slightly convex, sides broadly depressed and slightly reflexed, sides greatly rounded, subsinuate behind; anterior angles acutely acuminate; basal angles rectangular. Elytra with dorsum plane, sides parallel and margined. He also placed emphasis on the more conspicuous diagnostic characters—the more or less reflexed elytral margins, with the pronotal margins acute and reflexed, and the concave disk. The variety *texana* differs in its elongate and parallel form, the typical species being less elongate and with the elytral margins distinctly arcuate. Gebien (*9, p. 251*) in 1910 enumerated references to taxonomic literature on both the typical form and the variety *texana*.

A brief but able review of the economic importance of the genus Eleodes was given by McColloch (*18*) in 1918, in which he cited the existing principal records of injury and directed attention to the fact that very little has been recorded concerning this genus from an economic standpoint, because—

> It is only within recent years that the false wireworms have been recognized as pests of growing crops.

Swenk (*27, p. 336*) in 1909, in discussing injury to growing crops in southwestern Nebraska by *Eleodes opaca* Say, directed attention to the presence of *Eleodes suturalis* in suspicious numbers with that species. Hyslop (*14, p. 74*) in 1912 recorded the rearing of an adult of this species by Mr. Theo. Pergande from a larva injuring wheat in Saline County, Kans. This scarcity of information and lack of recognition as an economic pest is probably due to a number of causes. The larva bears considerable superficial resemblance to that of a true wireworm, of the family Elateridae, and it is likely that much damage to growing crops really caused by false wireworms has been reported as caused by the true wireworms. Then, too, the subterranean habit and obscure work of the larva of this false wireworm render its presence unnoticed without close search. Also, the adult is seldom observed, for it does not often appear from beneath cover in open spots except late in the evening or early in the morning, as the light and heat of the day drive it to shelter.

DISTRIBUTION

Colorado: Canyons near Boulder, H. F. Wickham (*3, p. 203*); Denver, altitude 5,183 feet, October, H. Soltau (*3, p. 203*); Gillette, altitude 9,933 feet, H. F. Wickham (*37, p. 294*); Golden, altitude 5,693 feet, May, H. G. Dyar and A. N. Caudell (*3, p. 203*), September, H. F. Wickham; La Junta, altitude 4,052 feet, H. F. Wickham (*37, p. 294*); Berkeley, H. F. Wickham (*37, p. 294*); Orchard, altitude 4,403 feet, H. F. Wickham (*37, p. 294*); Limon, altitude 5,360 feet, September, H. F. Wickham; Sterling, altitude 3,932 feet, August, H. F. Wickham.

Iowa: Lyon County, June, B. Shimek (*38, p. 33, 4*); Sioux City, altitude 1,104 feet, August, H. F. Wickham; "Western Iowa," T. H. Macbride (*36, p. 60*).

Kansas: Argonia, altitude 1,242 feet, March to November, J. S. Wade; Augusta, altitude 1,214 feet, August, E. G. Kelly; Belleville, altitude 1,514 feet, July, W. E. Pennington; Colby, altitude 3,138 feet, August, J. S. Wade; Dodge City, altitude 2,480 feet, June, V. King, August, J. S. Wade; Ellis, altitude 2,119 feet, August, J. S. Wade; Ellsworth, altitude 1,534 feet, April to October, E. G. Kelly; Garden City, altitude 2,829 feet, August, J. S. Wade; Harper, altitude 1,417 feet, June, J. S. Wade; Hays, altitude 1,999 feet, April, E. G. Kelly, July, H. E. Smith; Kingman, altitude

1,506 feet, November, E. G. Kelly; Liberal, altitude 2,839 feet, July, J. S. Wade; McFarland, altitude 1,021 feet, October, E. G. Kelly; McPherson, altitude 1,490 feet, October, W. Knaus; Marysville, altitude 1,154 feet, October, E. G. Kelly; Meade, altitude 2,503 feet, July, J. S. Wade; Mulvane, altitude 1,223 feet, September, V. King; Norton, altitude 2,275 feet, August, J. S. Wade; Plains, altitude 2,762 feet, July, J. S. Wade; Pratt, altitude 1,887 feet, November, E. G. Kelly; Riley County, July, August, E. A. Popenoe (*3, p. 203*); Salina, altitude 1,226 feet, October, E. G. Kelly; Scott City, altitude 2,971 feet, August, J. S. Wade; Sedgwick, altitude, 1,375 feet, September, E. G. Kelly; Wallace County, altitude 3,000 feet, F. H. Snow (*26, p. 68, 61*); Wellington, altitude 1,205 feet, March to November, E. G. Kelly, H. E. Smith, V. King, and J. S. Wade; Wilson, altitude 1,607 feet, August, V. King, J. S. Wade, October, E. G. Kelly; Winfield, altitude 1,114 feet, August, T. S. Wilson; Winona, altitude, 3,322 feet, April, E. G. Kelly.

Nebraska: Alliance, altitude 3,971 feet, H. F. Wickham, August; Alma, altitude 1,996 feet, J. S. Wade, August to September; Ashland, altitude 1,086 feet, October, J. S. Wade; Beaver City, altitude 2,147 feet, September, J. S. Wade; Belvidere, altitude 1,496 feet, May, C. E. Ward(*22*); Dodge County, Riley, Hubbard and Schwarz, Blaisdell (*3, p. 203*); Edgar, altitude 1,724 feet, October, E. G. Kelly; Elwood, altitude 2,765 feet, November, J. S. Wade; Fairbury, altitude 1,317 feet, October, E. G. Kelly; Hastings, altitude 1,932 feet, October, J. S. Wade; Holdrege, altitude 2,327 feet, October, E. G. Kelly; Oxford, altitude 2,077 feet, October, E. G. Kelly; York, altitude 1,634 feet, April, J. S. Wade.

New Mexico: Chico, altitude 6,882 feet, September, D. J. Caffrey; Clayton, altitude 5,054 feet, September, H. F. Wickham; Clovis, August, H. F. Wickham; Koehler, June, T. S. Wilson, October, D. J. Caffrey; Las Vegas, altitude 6,391 feet, September, D. J. Caffrey; Maxwell, altitude 5,894 feet, May, October, D. J. Caffrey; Vaughn, September, H. F. Wickham.

Oklahoma: Alva, altitude 1,336 feet, E. G. Kelly, August; Chickasha, altitude 1,091 feet, October, T. S. Wilson; El Reno, altitude 1,363 feet, June, E. G. Kelly; Mangum, September, Coll. U. S. Nat. Mus.; Texhoma, altitude 3,483 feet, November, E. G. Kelly; Woodward, altitude 1,893 feet, July, E. G. Kelly.

South Dakota: Buffalo Gap, altitude 3,257 feet, A. E. Hall (*3, p. 203*); Mitchell, altitude 1,297 feet, August, H. F. Wickham; Volga, E. C. Van Dyke (*3, p. 203*).

Texas: Amarillo, altitude 3,683 feet, August, H. F. Wickham; Cotulla, altitude 442 feet, May, F. C. Pratt; Denton, altitude 620 feet, March, F. C. Bishopp; Oakville, December, J. D. Mitchell (*13, p. 51*); Fredericksborough, May, J. D. Mitchell; Hebbernville, August, J. D. Mitchell; Knickerbocker, November, F. C. Pratt; Maverick County, May, J. D. Mitchell; Oakville; Plano, altitude 665 feet, July, E. S. Tucker; Rio Frio, May, F. C. Pratt; Sabine, altitude 17 feet, June, F. C. Pratt; Sherman, altitude 728 feet; "Texas," C. V. Riley (*3, p. 203*).

It is exceedingly probable that this insect has a wider distribution than the existing records indicate, and it is quite possible that it may occur over the greater part of the arid and semiarid regions of the Middle Western States. Wickham (*35, p. 86*) in 1890 says:

E. suturalis I never took west of Albuquerque, where it is rather rare.

In a discussion by the senior writer (*30, p. 2–3*) in 1921 of the ecological factors governing the distribution of this and related species, it was pointed out that its distribution is closely related to the marked variations of altitude from approximately sea level to over 6,000 feet and to the occurrence of soils of light, sandy type, as it is known that the larval stages thrive best in such soil. The adults, however, have been collected in small numbers several miles from such sandy locations.

FOOD PLANTS

Normally this insect fed upon the seed, root systems, and other portions of native grasses and other plants, upon dead vegetable matter in the soil, and occasionally upon living and dead animal tissue. As the prairies rapidly became settled farther and farther westward, however, these food plants were more and more replaced by cultivated crops, especially by winter wheat and other cereals, the grain of which when available

has become in large part their food. Of these introduced plants, the insect in the larval or adult stage, or in both stages, is known to feed more or less upon the following: Wheat (*Triticum vulgare* Vill.), oats (*Avena sativa* L.), corn (*Zea mays* L.), rye (*Secale cereale* L.), millet (*Setaria italica* Beauv.), alfalfa (*Medicago sativa* L.), kafir (*Holcus sorghum* L.), fleshy roots of sugar beets (*Beta vulgaris* L.), and several garden crops, notably the bean (*Phaseolus vulgaris* L.), and tubers of the potato (*Solanum tuberosum* L.). So far as known, wheat appears to be its favorite food, and this crop seems to suffer most from the depredations of the insect. Curiously enough, the injury to wheat is so great, and that occurring in the other crops enumerated is so slight by comparison, that a rotation introducing some of these crops, as will be shown later, has proved to be an efficient control measure. Although the beetle is known to feed to a greater or less degree upon practically all of the food plants enumerated, the greatest injury is wrought by the larva.

CHARACTER OF INJURY

The principal infestation of wheat occurs in the fall soon after sowing. As soon as the grains commence to soften in the process of germination, they are attacked by the larva. At times two or more larvæ may attack a single grain, and eat out its entire contents, leaving only the empty husk, but more often only one larva was found feeding upon a grain. The characteristic nibbling of the ends and gnawing out of the germ of the grain by the larva when once seen may afterwards be easily recognized. The young sprouts are also occasionally injured, though even when not attacked they wilt and die as soon as nourishment is no longer obtainable from the infested grain. When the plant is not attacked until well sprouted, the results are quite similar. Even the most vigorous plants seldom if ever put forth new roots.

In the fall the infestation is often confined to the more impoverished areas in a field, but in spring the larvæ may be present in numbers among the roots of tall and apparently healthy plants in the more productive areas. Where the surface is of a rolling character, infested fields soon present, in the fall, a parched or spotted appearance, the knolls standing out at first distinct and bare, although before harvest they become overgrown by grass and weeds. After the wheat has grown up somewhat around these devastated spots, the bare areas often become filled with dried thistles, blown there by the wind.

In addition to the injury caused by the larva, wheat in the shock or stack is damaged noticeably by the adult, which nibbles the ends of the grains.

The maximum injury to fall-sown grain occurs almost invariably during years when normal moisture is lacking. Frequently in the sandy, arid districts there are no rains during early fall, and the seed wheat lies in the ground for weeks after seeding. It is during these protracted dry seasons, while the grain is unable to sprout, that the larva is most injurious. During seasons when sufficient moisture is present at seeding time to cause the plants to sprout at once, less damage is done.

In only one year thus far, namely, that of 1910, has the pest invaded in destructive numbers the eastern portion of the area indicated. In the early summer of that year large numbers of adults were found in that area in the vicinity of straw stacks and beneath old weedy wheat bundles which had been discarded from the previous harvest. These waste

bundles were rather well distributed over the various fields, which thus become generally infested. The fall of that year, being a very dry one over the entire area of distribution, was favorable for this pest; since the wheat was seeded early and did not sprout until quite late, much of it was destroyed by the insect. Comparison of infested with noninfested fields showed that the former were trashy while the latter invariably were clean.

The insect has been known almost completely to destroy early sown seed wheat in early fall before sprouting has occurred, and growing wheat the following spring. More often, however, in dry autumns it attacks and destroys seed wheat in little spots or small areas all over a field, especially in the vicinity of straw stacks or piles of rubbish and weeds. Where the destruction is not complete, the injury is indicated here and there by the dwarfed or stunted plants. The larva is ravenous and very active, and sometimes as many as from four to six are present about a single wheat grain and its sprouts. Several full-grown larvæ have been found in 1 linear foot of a single drill row feeding upon the seed. Owing to their obscure, underground work a farmer frequently reseeds more than once in a single season without comprehending the true cause of his losses.

The percentage of yield lost through depredations of this pest can not always be determined. Frequently the extent of damage is not appreciated by the grower, especially during dry autumns, until late in the season when rendered apparent by the large, bare spots over the fields or the stunted, depleted condition of the growing crop. In extreme cases entire fields of wheat have been destroyed completely so that the crop was not worth harvesting.

DESCRIPTION

EGG (FIG. 1)

The egg is elliptic-cylindrical, bluntly oval in longitudinal section and circular in cross section. It is opaque ivory white, and the surface appears smooth both under low and high power of the microscope. It reflects light slightly from the lighted side. The shell is sufficiently tough not to become seriously distorted when the egg is rolled around in the soil. Average length 1.5 to 2 millimeters; width 1 millimeter.

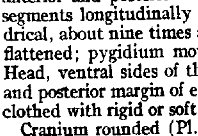

FIG. 1.—Egg of *Eleodes suturalis*.

MATURE LARVA[5]

Length 28 millimeters; color testaceous, with head and anterior portion of legs somewhat dark colored; presternum, prehypopleurum, anterior and posterior margins of prothorax, and posterior margins of the following segments castaneous-testaceous; anterior and posterior margins of prothorax and posterior margins of the following segments longitudinally finely striated. Surface corneous. Form elongately cylindrical, about nine times as long as wide (Pl. 1, C); dorsally convex, ventrally slightly flattened; pygidium movable in the directions up and down, conical, mucronate. Head, ventral sides of the thoracic segments, anterior portion of the sternum of first and posterior margin of eight abdominal segments, ninth sternum, legs, and pygidium clothed with rigid or soft setæ; rest of body glabrous with few, thin hairs.

Cranium rounded (Pl. 1, B), nutant, exserted, three-fifths as long as wide (from epistomal margin (*epi*) to occipital foramen), broadest medianly, dorsally somewhat convex. Anterior frontal angle (*fa*) rounded. Frons (*f*) three-fourths length of

[5] Description and Plates 1 and 2, by R. A. St. George.

cranium, a little wider than long with extreme width anteriorly; side margin convex. Epicranial halves (*epc*) meeting dorsally; epicranial suture one-fourth length of cranium; ventrally the halves are separated by the gula (Pl. 1, I, *gu*); dorsally with a few, laterally and ventrally with numerous thin setæ. Gula distinct, coriaceous, subquadrate, with tentorial pits (*tp*) just below middle of side margins. Clypeus (Pl. 1, B, *cl*) trapezoidal, widest posteriorly, length to extreme width as 1 to 4, medianly with slight transverse ridge, each side with two well-developed setæ near lateral margin; side margins of anterior half testaceous, rest membranous; posterior half with side margins testaceous, rest castaneous-testaceous. Labrum (*lab*) well developed, movable, transversely rectangular, almost three times as wide as long, anterior half membranous, posterior half castaneous-testaceous; anterior margin broadly emarginate, anterior corners strongly rounded; medianly also along lateral and frontal margins with slight deepening; disk on each half usually with a median transverse series of three or four setæ; along the side and frontal margins are about eight much longer and thinner setæ, with a few smaller ones between them; behind those along the anterior corner, but on the ventral side of labrum, may be two to three parallel series of shorter, stronger, somewhat curved setæ (Pl. 1, A).[6] Ophthalmic spots absent. Antenna closely behind the mandible, attached to distinctly colored rim below dorsal mandibular fossa; basal antennal membrane well developed, posterior part somewhat corneous; three articles; basal article subcylindrical, about as long as labrum, second article as long as basal, more clavate; apical article very small, cylindrical, bearing a few tactile hairs at apex; no supplementary appendix beside the apical article. Mandibles of right and left side differing in shape; both apically bifid (Pl. 1, E, G, a^1, a^2), each with one tooth (*t*) between apex and molar part (*m*); tooth of right mandible, however, prominent and placed near apex, that of left less developed and placed close to molar part; molar part of right mandible with bituberculate crown, that of left mandible with hollow crown; ventrally with cutting part deeply excavated, several soft setæ placed closely together near base, halfway between condyle and molar part; exterior surface ("back of the mandible") distally with a slightly carinate margin (*c*), proximally with a soft skinned, whitish swelling (*s*) mostly on dorsal surface; three strong setæ from anterior portion of swelling and three or four from posterior; portion opposite molar part and below whitish swelling excavated (*e*), with several small, soft setæ near ventral mandibular condyle; dorsal surface of mandible somewhat flattened. Maxilla dorsally completely covered by mandible, coriaceous (Pl. 1, I); palpus surmounting mala (*ma*) with one-fourth of its own length; maxillary palpiger (*pag*) small, ring-shaped; three articles; basal article somewhat clavate, slightly shorter than that of labial palpus; second article a little longer than basal, subcyclindrical, bearing a thin seta near apex on outer side; apical article half as long and thick as second, conical, apically covered with tactile hairs; mala on dorsal (buccal) surface (Pl. 1, D, *ma*) conical, a series of well-developed, somewhat curved setæ extending right back of and parallel to inner margin and a corresponding series along inner margin, rest of surface clothed with many thin setæ; mala on ventral (exterior) surface apically bearing one or two fine hairs (Pl. 1, I, *ma*); stipes (*sti*) fused with mala; base of stipes (*bs*) near articulation of cardo, short, bearing a few thin setæ; proximal half of inner margin (is_1) of stipes connected with maxillary articulating area (*ar*), distal half (is_2), right behind mala, free, bearing a few short, weak setæ; just below palpiger and along exterior margin many long, thin setæ; cardo (*ca*) about as long as maxillary palpus, entire, adjacent to curved hypostomal thickening (*hyp*) which lies between fossa for ventral mandibular condyle (*fm*) and fossa for tip of cardo (*fc*); inner margin of cardo near center with an indication of fusion with maxillary articulating area, posterior margin bearing a few short hairs. Maxillary articulating area (*ar*) protuberant, divided into halves; exterior half connected with maxilla, subdivided into an upper and lower portion, an oval elevation arising from upper portion, lower portion again divided in two and coriaceous, its exterior part connected with cardo, without setæ; interior half connected with submentum, entire, without setæ. Submentum (*sm*) coriaceous, trapezoidal, broadest posteriorly; side margins slightly concave and adjacent to maxillary articulating area; surface bearing numerous long, thin setæ medianly. Mentum (*me*) coriaceous, subquadrate, slightly wider anteriorly, side margins free; surface bearing a few long, thin setæ. The two stipites labii (*stla*) fused into a slightly chitinized unit carrying on each side a few short hairs; labial palpus about as long as stipites labii; two articles; basal article cylindrical; apical article conical, shorter than basal article, apically covered with tactile hairs; ligula (Pl. 1, D, *li*) small, narrow, conical, with a terminal pair of setæ; on buccal surface a parallel longitudinal series of thin setæ. Hypopharyngeal sclerite (Pl. 1, F. H, *hsc*)

[6] The size and arrangement of these setæ vary on opposite corners of the same specimen and on different specimens.

supported above hypopharyngeal bracon (*hbr*) by a chitinous plate from which it extends; elongate, subrectangular, somewhat rounded at base, projecting, strong, heavily chitinized; anteriorly tricuspidate; disk excavate with a slight swelling posteriorly. The hypopharyngeal bracon is a well-developed rod in the buccal membrane between the ventral mandibular articulations and the hypopharyngeal region; in the latter region the rod is heavily chitinized, near the former region slightly membranous. Epipharynx (Pl. 1, A, *eph*) forming the buccal surface of labrum, soft-skinned, with posterior, transverse, broad, sinuous, chitinous band that carries one pair of stublike, sharp teeth; on soft-skinned part anteriorly to these teeth a pair of tiny hooks; near anterior margin and below transverse chitinous band many scattered ring-shaped punctures.

Legs well developed, surrounded at base by a large articulating area (Pl. 2, E, *ar*). Prothoracic legs considerably stronger than those of mesothorax and metathorax. Articulating area laterally with a few (three or four) short hairs. Coxæ (Pl. 2, D, F, *cox*) of first pair attached so closely together that they are nearly contiguous at base, nearly as long as wide, coriaceous; many fine scattered hairs on exterior and interior surfaces; trochanter (*tr*) about as long as coxa, anterior face (Pl. 2, D) slightly coriaceous, posterior face (Pl. 2, F) membranous, on inner side distally with two spinelike setæ arising from a platelike callous wart, also a few thin hairs; femur (*fe*) as long and about as wide as coxa, anterior face coriaceous, usually armed with six or seven large spinelike setæ and two to three thinner setæ, also with many scattered hairs; tibia (*ti*) nearly as long as femur and about half as thick, with anterior face coriaceous, distally usually armed with five or six spinelike setæ and two to three more slender setæ, also many scattered hairs; tarsus (*ta*) about as long as tibia, falcate, strong but rather slender, surface facing backwards, excavate, basal portion enlarged, gradually narrowing to apex; on posterior tarsal side with round, rather soft-skinned region which bears distally, at base of excavation on either side, a strong chitinous seta. Second (Pl. 2, D, F) and third pairs of legs inserted farther apart, much more slender and anterior faces less coriaceous than the first pair; the arrangement of setæ and proportion of the articles vary somewhat from those of the first pair, but the two pairs are themselves alike. Coxa (*cox*) about twice as long as wide, with many scattered hairs except on exterior surface; trochanter (*tr*) about half as long and half as wide as coxa, distally with two spinelike setæ, also with a few other thin hairs; femur (*fe*) as wide as, but not quite twice as long as trochanter, armed, usually, with five chitinous spines, posterior face apically with two spinelike setæ, exterior surface with many fine scattered hairs; tibia (*ti*) about as long as but somewhat narrower than trochanter, usually armed with four chitinous setæ, posterior face with two spinelike setæ, exterior surface with very few scattered hairs; tarsus (*ta*) a little shorter than tibia, slender, surface facing backwards excavate, basal portion similar to tarsus of prothoracic leg.

Ventral intersegmental region between head and prothorax joined by slightly chitinous presternal area (Pl. 2, E, *y*) with two minute setæ each side and a slightly chitinized subconical area (*peu*) with two minute setæ which partly separate the presternal area and form the preeusternal subdivision of the eusternum; this joint region much wider than gula. Ventral intersegmental region between prothorax and mesothorax, and between mesothorax and metathorax, distinct, membranous, composed of poststernellar, preepipleural, and presternal areas.

Prothoracic eusternum (Pl. 2, E, *eu*) large, trapezoidal; the prehypopleural chitinizations (h_1 and h_2), and especially the prehypopleural chitinization h_1, large and strong, internally adjacent to ventral intersegmental region; sternellar region (*stl*) behind front legs, almost fused with eusternum, forming together a clepsydra-shaped region, poststernellum (*z*) transverse, somewhat spindle-shaped; prothoracic tergal shield (*te*) transverse, subquadrate, with anterior and posterior margins as mentioned above; right back of anterior margin as also near posterior margin a transverse series of setæ, usually composed of three setæ anteriorly and four posteriorly on each side; lateral margin with a few thin setæ, grouped mostly anteriorly and posteriorly.

Mesothorax and metathorax with large eusternal region; no separation of a preeusternal subdivision indicated, as in other forms such as *Merinus laevis* Oliv.[7] Presternal areas (Pl. 2, E, *y*) distinct, subtriangular, anteriorly slightly chitinized, bearing two setæ adjacent to poststernellum (*z*) of the preceding segment which has a few short hairs; prehypopleural chitinization (h_1) well developed, bearing many small setæ; posthypopleural chitinization (h_2) very small, not to be confused with adjacent oval chitinizations in articulating skin of leg; coxæ rather distant; poststernellum of metathorax not present; preepipleurum of mesothorax and metathorax (e_1) subtriangu-

[7] Although no separation of a preeusternal region is indicated, the areas correspond to those in *Merinus laevis* in which such a division is indicated. In this connection it may be pointed out that no well developed presternum is present in *Merinus laevis* as is in this form.

lar, the former carrying first thoracic spiracle, the latter the rudimentary second thoracic spiracle; epipleurum (e) of both segments well developed, lobe somewhat prominent and bearing a few setæ, more or less fused with the corresponding preepipleura; postepipleurum, (e_2) triangular; mesothoracic and metathoracic tergal shields (*te*) transverse, subrectangular, about three times as wide as long,[8] right behind anterior margin with a dark transverse line;[9] posterior margin darker than rest of segment, longitudinally finely striated, setæ arranged as on protergum. The typical abdominal segments with fused sternal areas (*ster*) covered by a single transversely rectangular shield, posteriorly darker, with band longitudinally striated; setæ on first seven terga with two transverse series, the anterior of these usually having four setæ on each side and posteriorly two; on eighth tergum the setæ arranged similarly anteriorly, posteriorly with three on each side; sternum of first abdominal segment anteriorly densely set with setæ; a few extending along lateral margin, similar arrangement lacking on other abdominal segments; posteriorly with two short setæ on each side; hypopleural region (*hy*) indistinct, epipleural region (*ep*) narrow, adjacent to tergal shield, anteriorly, on first abdominal segment, with from one to four small setæ, on rest of segments a single seta only; tergal shield (*ter*) laterally carrying spiracle, above which is a dark line; second and third sterna usually with three or four short setæ grouped together, near which is a long, thin seta anteriorly on each side and posteriorly with two long, thin setæ on each side. Sternum of third to eighth segments usually with two setæ anteriorly and two posteriorly near lateral margins; sternum of eighth segment with setæ arranged anteriorly as on third to eighth, posteriorly with several small setæ arranged in a transverse series along margin, first six abdominal segments transverse, seventh and eighth subquadrate.

Ninth abdominal segment smaller than preceding segment, coriaceous, with dorsal part or pygidium conically produced (Pl. 1, C; Pl. 2, A, G, H), above somewhat concave, below broadly convex, with apex pointing upward, mucronate; apex slightly chitinized, on each side with a short spinelike seta; lateral margin set with a series[10] of strong, short, spinelike setæ, below which are many soft hairs; near anterior margin a transverse series of short hairs, back of which is a transverse series of longer, thin hairs, and posteriorly a few setæ; convex surface with scattered fine setæ; ventral part of ninth segment small, transverse, soft, with many short setæ. Tenth segment separated from ninth above and below by articulating membrane. Tenth abdominal (anal) segment (Pl. 2, A, H) small, with upper and lower transverse anal lips, the lower lip on each side with conical and, except at tip, setose ambulatory papilla. Spiracles (Pl. 2, B) annular, broadly oval, transversely placed; opening linear, unprotected by hairs, at bottom of cup-shaped peritreme.

The foregoing description conforms with Dr. A. G. Böving's (*30, p. 326-329, pl. 31, 32*) description of the larva of *Embaphion muricatum*, with which it is closely related. The following characters of the larva of Embaphion, however, will separate the two species.

Pygidium pointing upward, subconically produced, above somewhat flattened, apex obtuse, lateral margin with a series of strong, short setæ; whole surface with fine scattered setæ; whitish swelling on back of mandible, opposite the molar part, with three to four strong setæ from the anterior portion, two from the posterior; ventral intersegmental region between head and prothorax about the width of gula,[11] with two minute soft setæ on each side of the slightly chitinous presternal area; two transverse ophthalmic spots present just behind antenna; ligula on buccal surface not setose; disk on each half of labrum with median transverse series of five large setæ and an anterior series of three long, thin, and straight setæ; right behind these but on ventral side of labrum another series of four shorter, stronger, and curved setæ; femur and tibia of prothoracic leg each usually armed with fine spinelike setæ.

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[8] Because the tergum is so convex the proportions in the figure do not quite agree with the text.

[9] This line is not as well developed on the metathorax and may even be lacking.

[10] There are usually from 9 to 11 setæ on each margin. Because they differ somewhat in number in various specimens, and sometimes on opposite sides of the same specimen, they do not offer very reliable characters.

[11] This character will separate Embaphion from all Eleodes larvæ as represented in the United States National Museum Collection, which consists of the following material given to the Museum by the senior author: *Eleodes acuticauda* Lec.; *E. carbonaria* (Say), *E. extricata* (Say), *E. fusiformis* Lec., *E. hispilabris* (Say), *E. longicollis* Lec., *E. opaca* (Say), *E. obscura* (Say), *E. obsoleta* (Say), *E. sponsa* Lec., and *E. tricostata* (Say).

PUPA (FIG. 2)

When first formed the pupa is opaque white, but after a short time the eyes become visible and the thoracic segments become more distinct and take on a pale cream color. No other notable change takes place until the time for emergence. Just prior to emergence the elytra and thorax become yellowish brown. Pupa dorsally acute, ventrally somewhat flattened. Head pressed to prosternum. Pronotum rather broad and protruding above the head so as to make the head nearly invisible from above. Caudal segment bearing a pair of thick fleshy spinelike lobes directed posteriorly. Between dorsal and pleural abdominal plates an irregular deep depression forming a distinct submarginal groove. Pleural margin of abdominal segments bearing irregular semicrescentic plates each having tuberculiform bristles in fanlike arrangement. Head, antennæ, and legs free. Body smooth. There is considerable variation in size. Approximate average length 23 millimeters, width 8.5 millimeters.

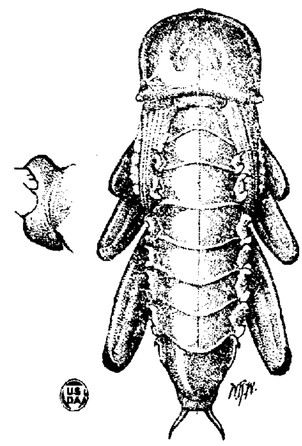

FIG. 2.—Pupa of *Eleodes suturalis*, dorsal view; at left, left lateral lamella (=lamina motoria of Schiödte) of second abdominal segment.

ADULT (FIG. 3)

The following description is taken from Blaisdell (*3, p. 199–202, pl. 1, fig. 19*):

Oblong, more or less strongly elongate, dorsum flattened and slightly concave, black frequently with a broad reddish band along the elytral suture, epipleuræ often tinged with the same color.

Head a little less than twice as wide as long and scarcely one-half as wide as the pronotum surface plane to slightly convex, frequently more or less impressed along the frontal suture, sometimes transversely so between the eyes, and laterally within the moderately prominent sides of the frons, opaque, moderately, coarsely, irregularly, and densely punctate, usually with small impunctate areas. *Antennæ* rather stout, scarcely reaching the prothoracic base; outer four joints slightly compressed and just perceptibly dilated; third joint about equal to the next two combined; fourth, distinctly longer than the fifth; the latter to the seventh, inclusive, subequal and slightly longer than wide; eighth, triangular and about as long as wide; ninth and tenth, suborbicular; eleventh, short ovate.

Pronotum widest at the middle and about one-half wider than long; *disc* opaque, smooth, slightly convex, finely and sparsely punctate, with small impunctate areas about the center, frequently with irregular impressions; laterally longitudinally impressed from within the apical angles to a very short distance in advance of the basal angles, terminating in feeble basal impressions, the depressions are generally transversely rugulose; *apex* deeply emarginate and more or less obsoletely margined *sides* broadly and more or less strongly reflexed, evenly arcuate or sometimes very feebly and broadly angulate at middle, slightly sinuate in front of the basal angles marginal bead moderately coarse; base truncate and feebly trisinuate, distinctly margined, two-fifths to one-half wider than the apex; apical angles acute, subacuminate, prominent and more or less everted; basal angles rectangular.

Propleuræ opaque and smooth, very finely and sparsely to obsoletely, muricately punctate, more or less rugulose at times, and defined from the reflexed pronotal margin by a longitudinal concavity.

Elytra oblong, one-third to twice as long as wide and more or less opaque; *base* feebly emarginate, and about equal to the contiguous prothoracic base; *humeri* obtuse and not prominent, rounded beneath the basal angles of the pronotum; *sides* evenly arcuate to subparallel, apex scarcely to feebly produced; *disc* plane to slightly convex very suddenly deflexed laterally, angle of deflexion forming an acute and moderately reflexed margin, which becomes obsolete a short distance before the apex, more or less suddenly obliquely declivous posteriorly; *surface* sulcate, intervals feebly convex each with a single series of rather distantly placed punctures, the four inner sulci with but a single series of closely placed submuricate punctures, remaining sulci

with numerous closely and irregularly placed punctures, which become denser and rather more strongly muricate towards margin; apical declivity somewhat more strongly sulcate and scabrous; inflexed sides not convex, obsoletely sulcate, irregularly and muricately punctured.

Epipleuræ moderately narrow, uncinately dilated beneath the humeri, and gradually narrowing to apex; surface usually more or less obsoletely punctate.

Sterna and *parapleuræ* more or less obsoletely or strongly punctate and rugulose.

Abdomen finely and more or less sparsely, obsoletely punctate and rugulose.

Legs moderate. Anterior femora armed in the sexes; protibial spurs and protarsi nearly alike in the sexes, the spurs are quite strongly divergent. The first joint of the protarsi is more or less thickened and slightly produced at apex beneath, bearing a tuft of yellowish pubescence.

Male.—About twice as long as wide. Antennæ scarcely reaching to the basal margin of the prothorax. Elytra moderately, suddenly, and obliquely declivous posteriorly; apex slightly acuminate. Abdomen slightly oblique, moderately convex, broadly impressed on the first two segments. Anterior femora with an acute tooth about one-fourth distance from the apex; posterior spur of the protibiæ apparently a little longer and slightly stouter than the anterior, frequently they appear to be quite equal in length, both are rather stout and acute; first joint of the protarsi with the produced tip beneath rather thick and bearing a small obtuse tuft of modified spinules, groove not evident.

Female.—Less than twice as long as wide. Antennæ reaching to about the posterior fifth of the prothorax. Elytra quite suddenly obliquely or vertically declivous posteriorly. Apex obtuse. Abdomen horizontal, evenly and strongly convex. Anterior femora with a small obtuse tooth, sometimes scarcely more than sinuate in outer fourth; posterior spur of the protibiæ a little longer and stouter than the anterior, both are acute, moderately thick, and gradually narrowed from the base; first joint of the protarsi slightly and transversely produced at tip beneath, bearing a transverse tuft of spinules, which is more or less acute, groove more or less obsolete.

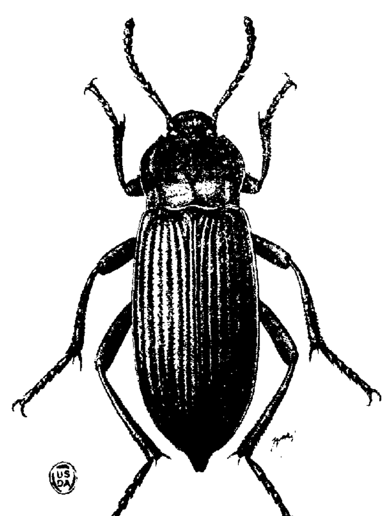

FIG. 3.—Adult of *Eleodes suturalis*, dorsal view.

The male genital characters do not apparently show any racial differentiation.

Male.—Edeagophore of the ual oblong-ovate form.

Basale oblong, scarcely arched, d may be sparsely punctate terally at apex.

Apicale rather broadly triangu-r, moderately depressed, sur-ce more strongly convex api-lly, with a median membranous oove in apical half; sides rather raight to slightly arcuate; apex arcely produced and more or ss deflexed, subacute; base oadly lobed at middle, and sin-ite laterally.

Sternite transverse. Each lobe ith the external border more or ss evenly arcuate, and the inter-l short and straight to feebly arcuate, with apex rounded; surface densely punctate d setose in apical two-thirds, setæ quite long and not extending upon the membrane ross the sinus; the latter nearly closed by the same. The lobes internally at base d cephalad to the sinus are rendered semicircularly sinuate by an interlobar trans-rsely oval membranous area, the membrane of which is frequently transversely gose.

LIFE HISTORY AND DEVELOPMENT

The insect hibernates in the adult stage beneath piles of rubbish, grass, weeds, and refuse, or buried in soft sandy soil, and in the burrows of small mammals; it also hibernates in the larval stage, buried deeply in the soil. In the latitude of southern Kansas the adult is abroad in the fields depositing eggs in early spring, and is present in the fields until late November. Some of the adults have been known to live two or three years. The egg is deposited in soft loose soil at a depth of about three-fourths of an inch to 1 inch. Frequently from 10 to 60 eggs are found in a single nest. The egg hatches in from 8 to 10 days, depending on the moisture and temperature, and the young larva a short time thereafter begins to feed very actively upon vegetable tissue and roots in the soil. Where development occurs under favorable weather conditions and with adequate food supply, the larva grows rapidly, reaches maturity, and enters the pupal stage in about 110 to 130 days, though this period may be accelerated or prolonged by abnormal conditions. The pupal stage continues for a period varying from 10 to 22 days, during which time the insect is comparatively motionless in an earthen cell at a depth of about 3 inches in the soil and takes no food, and at the end of this period transformation to the adult stage occurs. This adult in turn often produces another generation of larvæ in late summer. Such larvæ when about half grown (and at a depth of about 2 to 5 inches in the soil at wheat-seeding time) reach their period of greatest destructiveness about the time the newly sown fall wheat is coming through the ground. Numbers of the larvæ of this generation usually overwinter as larvæ at considerable depths beneath the ground or in loose soil beneath refuse. Some of these larvæ have been found in November at a depth of 7 inches and in December at a depth of 14 inches in the soil. It should be noted that there is considerable overlapping of generations, hence larvæ of widely varying size often coexist in the same field.

The newly hatched larva does not immediately become active but remains for a little while in the soil, at the place where the egg was hatched and in the cavity formerly occupied by it. The toughness of the eggshell is indicated by the fact that the empty shell retains its shape for some time after the larva has emerged therefrom. The integument of the newly hatched larva is rather tender but nevertheless enables it to survive rather rough handling. When newly hatched the larva averages 2.5 millimeters in length and about 0.3 millimeter in width, and is semiopaque white. The general proportions of the newly hatched larva do not vary to any noticeable degree from those of the older larva, but there is an occasional slight variation in size. The larva begins to feed lightly not long after hatching, and appears to grow with greatest rapidity during the first three or four weeks, as it more than doubles in size during this period. Following the second molt the rate of growth becomes less marked. Larvæ invariably are present in infested fields in greatest numbers in the vicinity of straw stacks, or in the absence of these, in the neighborhood of or beneath scattered bundles of grain which contain such a large percentage of weeds that they have been discarded and left behind by the harvesters. It has been repeatedly noticed that the infestation in many fields invariably appears to originate and spread from such straw stacks and is always more severe in their vicinity. In fields not sown to wheat the larvæ are not found scattered generally over the field but are usually grouped in numbers in the soil

round straw or grain stacks or other shelters, and have been found in he moist soil far under such straw stacks beneath a layer of straw ; feet in depth. In fields recently sown to wheat they are usually lisseminated irregularly over the field, but are in greatest numbers near he shelters, and are sometimes in such abundance that as many as 165 larvæ of this and related species have been found in three adjacent rill rows within 3 linear feet.

Cannibalism is rather common, both under artificial rearing and under normal field conditions, and where the larvæ are abundant in a field it is not uncommon to find numbers of partly devoured larvæ here and there at the spots of their greatest activity. This is most noticeable, however, under field conditions during the early period soon after germination of the grain, when the larvæ are most busily feeding and where conditions may be such as to produce crowding. Under average field conditions sufficient numbers of larvæ are not destroyed in this way, however, to render cannibalism a factor of value from an economic standpoint, as this larva is normally phytophagous. The larva appears sensitive to disturbance of any kind. If touched it will often feign death and remain motionless for a time before attempting to escape. If taken between the fingers, the pressure sufficient to hold it causes it to make the most frantic efforts to escape, and it twists and wriggles its body with greatest activity into almost every possible position, ejecting quantities of a colorless fluid apparently from between its dorsal segments. Presumably this fluid is defensive or repulsive and is one of its means of protection from birds and other enemies of similar feeding habits.

The larva, being very quick and active, can move easily over smooth surfaces and bury itself in the loose soil with greatest ease. It is able also to penetrate compact soil with little apparent difficulty, since it has been found working in ground of considerable hardness at a depth of 2 inches, but if the soil be fairly loose, its friableness and dryness appear to facilitate larval movements. When very young it is unable to survive long in perfectly dry earth, but as it becomes larger it does not appear to be greatly affected by this condition, although it prefers slightly moist soil. The larva is keenly susceptible to an overabundance of moisture and often comes to the surface of the ground and remains there for several ours following hard, dashing rains. It is negatively phototrophic and hen exposed to light hides with the utmost rapidity under any shelter can find. When artificially confined in a Petri dish, it soon crawled eneath the layers of filter paper or blotting paper at the bottom of the essel.

When ready to molt the larva remains comparatively motionless for ome time before the skin splits and it is able to free itself therefrom. Molting occurs in its channels, and wriggling from its exuvia, the larva emains comparatively inactive for a short time until the new skin has hardened somewhat. Considerable difficulty was experienced in obtaining the length of instars, as it was necessary to do this under aboratory conditions, and a number of types of cages were tried and discarded before one suitable for the purpose could be evolved. The rregularity in time of molting, the proper regulation of food and moisture, and the difficulty of finding the exuviæ in the cage also added to the complexity of the problem, and many hundreds of larvæ died in various forms of cages and through a variety of causes before the desired information could be obtained. The type of cage from use of which satisfactory data at last were secured consisted of a 2-ounce, seamless,

tin salve box, in which was placed a one-fourth inch layer of plaster of Paris, covered by a thick coating of India ink, and a small disk of dark-colored blotting paper slightly smaller than the diameter of the box. The newly hatched larva when isolated in such a cage, having the plaster of Paris slightly moistened, and with split wheat grains for food, appeared to thrive normally to pupation at an even temperature of about 60° F. as long as the moisture therein could be kept properly regulated. Curiously enough, soil in the cage was not an absolute essential. It was found that normally there are six instars. The length of these instars, according to records made daily from observations upon the survivors of 50 isolated specimens, averaged as follows: From hatching to first molt, about 6 days; from first to second molt, about 10 days; from second to third molt, about 21 days; from third to fourth molt, about 26 days; from fourth to fifth molt, about 14 days; from fifth to sixth molt, about 27 days; from sixth molt to pupation, about 18 days. It was found, however, that the length of the period between instars was often prolonged because of temperature, hibernation, moisture, quantity of food, and other like factors.

Many of the larvæ in the field reach the fourth or fifth instar during late fall and overwinter in that condition. During this period they penetrate to considerable depths in the soil, feed but little, and are comparatively inactive. Commencing early in March, if the spring is a normal one, they feed until ready to pupate. Just before pupation the larva prepares its earthen cell and enters upon a semiquiescent stage which continues from 4 to 10 days.

The period of pupation lasts for approximately 17 days, after which the adult emerges. It is comparatively inactive for a short time after this until its chitin has turned from pale brown to black and has become harder. The recently emerged adult is always brighter and has a deeper gloss than an older one. Mating most frequently takes place about 6 or 7 days after issuance from pupation, and egg laying begins about 20 to 22 days thereafter. There is seldom much variation in the method of oviposition; the female burrows into the soil to a depth of approximately three-fourths to 1 inch, loosens up a tiny area of soil, and at intervals deposits there the eggs in bunches consisting of two or three to several dozen, within an area having a diameter of not more than 2 inches. The average number deposited by a series of 100 females, from which count was kept, was 108 eggs, while the maximum number deposited by a single female within this series was 335 eggs. When disturbed, the adult has a curious habit, common to other species of this group, of standing still, placing its head to the ground, and tilting upward the posterior portion of its body until it appears fairly to stand upon its head, and it remains motionless in that position for several minutes. By and by, if not further disturbed, it resumes its normal position and continues its activities. If sufficiently annoyed, it ejects in a lateral direction from anal glands a strong astringent fluid having a highly offensive odor and evidently protective in function. Gissler (*10*) in 1879, in discussion of another species of Eleodes of similar habits, first described this secretion and the glands from which it is ejected.

The adult, being crepuscular, reaches its period of greatest activity during the cooler portion of the day, in early morning, in late evening, or during twilight hours, and like other nocturnal insects is not noticeable in fields during the brighter, warmer hours of the day except when deliberate search is made for it. It may then be found under grain

bundles, shocks, and edges of stacks, in burrows of small mammals, beneath piles of manure and dried Russian thistles, along fence rows, or beneath other convenient shade or cover. The adult does not crawl up into such bundles or shocks to any noticeable degree, but remains on the ground beneath them, and appears to prefer shocks or bundles which have settled rather closely to the ground instead of those resting lightly upon the stubble. It also selects for shelter the old dried piles of weeds and trash rather than fresh, green, newly cut piles of such débris. The amount of excrement present with the adult when found indicates that it often remains for a considerable period in the same spot. It also has been noted that an adult is occasionally present at night beneath street lights in towns within the infested areas, but it is not attracted to lights in large numbers. Webster (*32, p. 32*) in 1912 stated that an adult of *Eleodes suturalis* was observed devouring chinch bugs (*Blissus leucopterus* Say) at Wellington, Kans. D. J. Caffrey in 1915, while conducting a series of observations relating to insects predacious upon the New Mexico range caterpillar (*Hemileuca oliviae* Ckll.) noted that adults of *Eleodes suturalis* would not feed upon dead Hemileuca larvæ.

At the approach of cold weather in late fall the adult seeks a hibernating place, usually beneath the rubbish previously used as shade and cover, and there it often penetrates to a considerable depth in the soil. It is probable that little or no food is taken during hibernation, and at such times, when an adult has been dug out or uncovered, it seems to be in a semidormant condition, and even after being taken into a warm room does not resume its normal activity for some hours. If kept out of hibernation and subjected to winter weather it speedily perishes.

NATURAL ENEMIES

Swenk (*27, p. 335–336*) in 1909 and McColloch (*19, p. 191*) in 1919 recorded that they experienced more or less difficulty in conducting successful rearings of false wireworms because of the presence of what was presumably a bacterial disease of the larvæ. A disease similar to that discussed by them also was encountered by the writer in rearing work with *Eleodes suturalis*. The presence of this upon a larva would first be noticed in the form of one or more small, irregular, reddish-brown spots on the thoracic and abdominal segments, and these spots usually would become larger in area until the death of the larva. In a number of instances it appeared to cause the death of the larva without having increased appreciably in size; at other times it would become larger until it encircled the body, and the larva notwithstanding would remain alive and reach the adult stage apparently without serious inconvenience; normally, however, the spot increased steadily in diameter and in doing so sooner or later caused the death of the larva. Presumably the disease was capable of spreading to other larvæ, for healthy larvæ, when placed with sick ones, frequently contracted the disease, though the customary isolation of the larvæ in individual cages probably was responsible for preventing its general spread.

The larva, while under laboratory conditions, occasionally was attacked by fungi, notably *Sporotrichum globuliferum* Speg. and *Metarrhizium anisopliae* Metschn. McColloch (*19, p. 191*) also noted the presence of fungi, presumably of these species, in his rearing work.

If the cage containing the larva was not sterilized regularly and carefully various species of tiny soil mites (Acarina) occasionally would be present in scattering numbers.

A number of insects may be associated under normal field conditions with the larval and adult stages of this species and thus far a few of these, notably the larvæ of a species of Calosoma, of *Harpalus caliginosus* Fab., and of an undetermined species of robber-fly of the genus Erax, are known to attack *Eleodes suturalis* larvæ. Various species of field mice, snakes, frogs, spiders, and centipedes also frequently are associated with the insect in varying numbers, but their presence usually does not appear seriously to disturb its activities. The pupa of *E. suturalis* sometimes has been attacked and killed by the ant *Tetramorium caespitum* L., and the adult occasionally has been attacked by the ant *Pogonomyrmex occidentalis* Cress. The adult is freely eaten by chickens.

Barrows and Schwarz (*1, p. 64*) in 1895, in discussing food habits of the common crow, stated that the finding of some specimens of the genus Eleodes in a few stomachs of crows from Kansas and Nebraska leads them to the supposition that if a larger number of stomachs from that region could be examined, specimens of this and allied genera would be found well represented, and they add:

> These beetles, so characteristic of the fauna of the arid region of the West, fulfill most of the requirements of insect food preferred by the Crows; they are terrestrial, large, hard, and possess a strong, offensive odor.

The records of the Bureau of Biological Survey of the United States Department of Agriculture show that birds of the following species have fed on beetles of the genus Eleodes, the fragments of which could not be specifically identified though it is probable that some of them have been *E. suturalis* Say: Crow, *Corvus brachyrhynchos* Brehm; hairy woodpecker, *Dryobates villosus* L. (*2, p. 15*); sparrow hawk, *Falco sparverius* L.; road-runner, *Geococcyx californianus* Lesson; red-headed woodpecker, *Melanerpes erythrocephalus* L.; mocking bird, *Mimus polyglottos* L.; sage thrasher, *Oreoscoptes montanus* Townsend; magpie, *Pica pica hudsonia* Sabine,robin; *Planesticus migratorius* L.; purple grackle, *Quiscalus quiscula hudsonia*; Sabine, meadow lark, *Sturnella magna* L.; Arkansas kingbird, *Tyrannus verticalis* Say; yellow-headed blackbird, *Xanthocephalus xanthocephalus* Bonaparte.

The Bureau of Biological Survey has records of a number of other species of Eleodes which are preyed upon by birds.

Riley (*21, p. 432; 22*) records rearing a parasite from an adult of *Eleodes suturalis* collected by C. E. Ward, Belvidere, Nebr., on April 27 which later was identified as *Perilitus* sp. The edges and corners of a cigar box in which the host beetle had been kept overnight were lined with the elliptical whitish cocoons of the parasite. Nearly three weeks elapsed between the time the larvæ left the host and the emergence of the parasites. A dissection of the beetle showed that most of the contents of its abdomen had been absorbed. Viereck (*29, p. 561*), in 1913 published a description of this species, naming it *Perilitus eleodis* (fig. 4) the type being reared from an adult of *Eleodes suturalis* collected a Argonia, Kans. The specimens formerly received from Belvidere, Nebr are indicated as mostly stramineous. It was found that the species wa closely related to *Perilitus gastrophysae* Ashmead—

> of which it may prove to be only a variety. . . .

McColloch (*18, p. 220*) in 1918 reared a number of adults of *Perilitus eleodis* from *Eleodes tricostata* and fortunately secured considerable noteworthy information of value on the life history of the parasite. He also (*19, p. 190*) reared the same parasite from *E. opaca* Say.

Several hundred specimens of *Perilitus eleodis* were reared at intervals from July 18 to October 22 from adults of *Eleodes suturalis*. They issued as larvæ from the anal opening of the adult hosts and pupated as tiny silken cocoons occurring in clusters here and there over the bottom of the cages. These cocoons were sometimes attached to a portion of the cage walls and sometimes were matted together in the soil which had been placed in the cages to facilitate egg laying. The adult parasites soon after emergence became active and moved about restlessly over the cages, and when present in cages containing host beetles would crawl about over them and attempt to oviposit promiscuously at any of the body sutures, usually on the ventral side. The beetle appeared to be in extreme fear of these parasites and would scramble around in greatest excitement as soon as one of them drew near. It would also make frantic efforts to push off the parasites when attacked by them. Upon finding a soft spot in which to place the egg, the rather long and upcurved ovipositor of the adult parasite was thrust through a suture of the body wall of the beetle. Each beetle thus attacked was isolated for further parasites, but unfortunately in no instance were additional ones obtained. The beetles sometimes lived for several hours after the parasites issued. The maximum number of parasites secured from a single host individual was 121. *Perilitus eleodis* also was reared by the senior writer from adults of *Eleodes hispilabris* Say, *E. obsoleta* Say, *E. tricostata* Say, and *E. extricata* Say.

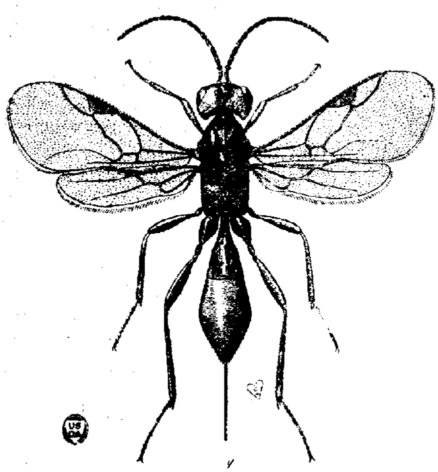

FIG. 4.—*Perilitus eleodis*, a parasite of the adult of *Eleodes suturalis*: Adult female.

CONTROL MEASURES

Extensive experiments conducted some years ago by Curtis (*6, p. 170–78*), Treat (*28, p. 82*), Ormerod (*20, p. 111–118*), Weed (*34, p. 213*), Comstock and Slingerland (*5, p. 199–250*), and Forbes (*8, p. 48–51*) in attempting to find a remedy for true wireworms, afford clues in the search for control measures for this pest, for although these entomologists failed to find remedies which were in every way satisfactory, their work was of great value in pointing out the uselessness of several suggested schemes for avoiding crop injury by subterranean pests. Bearing in mind the suggestions embodied in the published records of their work,

the senior writer's experiments for destruction of *Eleodes suturalis* were carried on along somewhat similar lines, though in a supplementary way without duplication of experimental work and with special reference to the habits of the species under consideration. Emphasis was placed on experiments for the protection of the planted seed, the destruction of the larva, and the destruction of the pupa and beetle.

As the protection of the seed was deemed more especially desirable much attention was given to this phase of inquiry. Wheat seed was treated with a great variety of preparations and then subjected to attack by the larva in the hope of finding some effective repellent or poison but in every case these proved ineffective, for they not only failed to kill the larva, but, what was worse, they often retarded or entirely prevented the germination of the seed. Coating the seed or soaking it in solution or preparations of tar, shellac, copperas, strychnine, cyanid of potassium turpentine, kerosene, and similar substances all proved ineffective and of no practical value since either the cost was prohibitive or the larva devoured quantities of treated kernels and apparently experienced no ill effects therefrom. It is believed that in these experiments the impracticability of all methods of this general character in attempting to protect the seed was fully demonstrated.

In experiments relative to the destruction of the pupa and beetle it was found that all the various insecticides applied to the soil in hope of killing the insect infesting it proved ineffective if used in reasonable amounts. While it is true that some of these substances, such as crude petroleum or turpentine, will destroy the insect when used in large quantities, the amount and strength necessary to accomplish this result often was so great as to destroy all the vegetation in the infested areas and, further, to render the cost of application over large areas prohibitive. It was also demonstrated that certain fertilizers may have a slight value as insecticides, though their principal merit appears to be in the stimulation of the growth of the plant and in soil drainage. Salt, lime, crude potash cyanide of potassium, and other substances likewise have been found impractical since they either do not affect the larvæ at all, or to do so must be used in quantities so enormous that they either prove destructive to all vegetation or are too expensive. It was found that trapping the larva and the adult with baits of poisoned vegetables may have a possible value in intensive farming on small acreages, but it is impracticable with extensive acreages of winter wheat and with farming methods as practiced in the infested areas. At the period of their greatest abundance in summer repeated experiments were performed in attempts to kill the adults with poisoned bran mash, using the standard formulas for grasshopper control, but the mortality caused by use of these baits was exceedingly small and would not warrant expectation of obtaining practical control by such means. Late fall or spring plowing would be very effective in turning up and destroying the pupa, but as the crop on the ground usually is winter wheat, the nature and condition of the host plant at that particular time does not of course render such treatment at all practicable.

The easiest and most effective control measure thus far indicated is the judicious rotation of wheat with other crops for two or more seasons, especially with corn or some other crop which may be regularly and frequently cultivated. Infestations are always much heavier where rotation has not been practiced. It is also highly desirable that all accumulations of rubbish, dead grass, matted weeds, old straw stacks,

old discarded bundles of mixed weeds and grass, and other shelter and hibernating quarters be burned or entirely removed. Especial emphasis should be placed on the burning of piles of dead Russian thistles, which at present are so common in fields and along the roadsides of farms in the central and western portion of the infested region. Although the scope of this paper does not permit detailed discussion of control measures for more than one species within this family, it is probable that effective control measures will be found not to differ greatly for most of the other related species of economic importance.

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PLATE 1

Eleodes suturalis

A.—Epipharynx (*eph*) and anterior margin of labrum of larva.

B.—Head of larva from above: *lab*, labrum; *cl*, clypeus; *fa*, anterior angle of front; *epi*, epistoma; *f*, frons; *epc*, epicranium.

C.—Lateral view of larva.

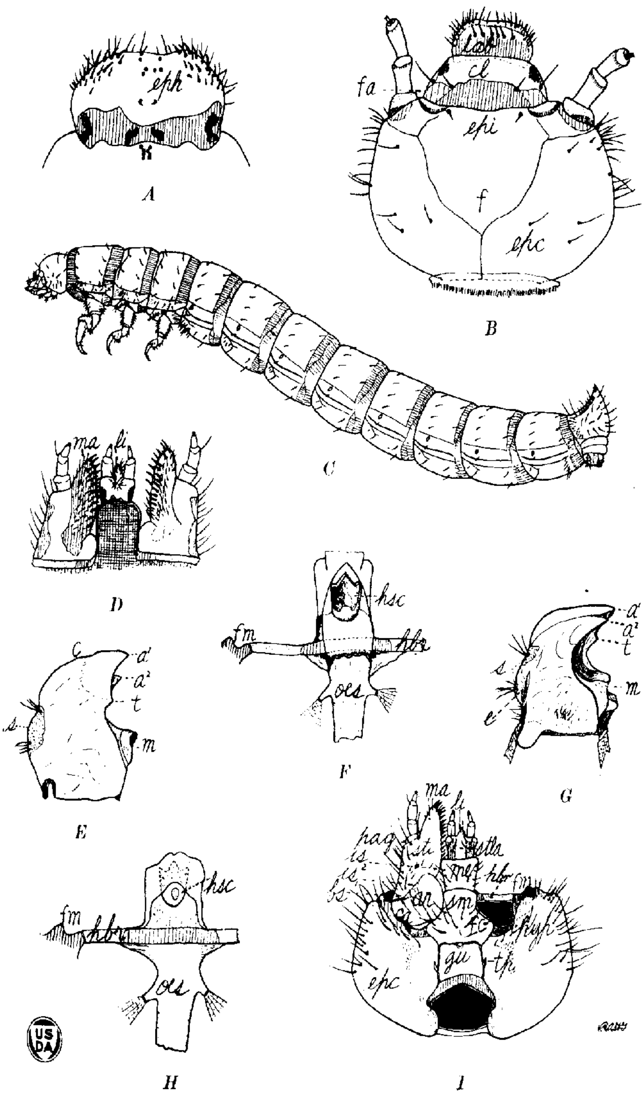
D.—Maxillæ and ligula of larva seen from buccal cavity: *ma*, mala; *li*, buccal surface of ligula.

E, *G*.—Dorsal side of left mandible of larva and ventral side of right, respectively: a^1 and a^2, bicuspidate apex; *t*, tooth of cutting edge; *m*, molar part; *c*, carinate edge on exterior side of cutting part of mandible; *s*, soft-skinned, seta-bearing elevation below carinate edge; *e*, excavation below soft-skinned elevation.

F.—Hypopharyngeal region, œsophagus, and hypopharyngeal bracon of larva, corresponding to piece removed from D: *hsc*, hypopharyngeal sclerite; *hbr*, hypopharyngeal bracon; *fm*, mandibular ventral fossa; *oes*, œsophagus.

H.—Hypopharyngeal region of larva; same as *F* but reversed: *hsc*, base from which hypopharyngeal sclerite originates; *hbr*, hypopharyngeal bracon; *fm*, mandibular ventral fossa; *oes*, œsophagus.

I.—Second and third mouth parts of larva from ventral side: *gu*, gula; *tp*, tentorial pit; *sm*, submentum; *me*, mentum; *stla*, stipes labii; *li*, ligula; *hyp*, hypostoma; *fm*, fossa for mandible; *hbr*, hypopharyngeal bracon; *fc*, fossa for cardo; *ar*, maxillary articulating area; *ca*, cardo; *sti*, stipes maxillaris; *bs*, base of stipes; is_1 and is_2, inner margin of stipes; *ma*, mala maxillaris (probably lacinia); *pag*, basal membrane of maxillary palpus; *epc*, epicranium.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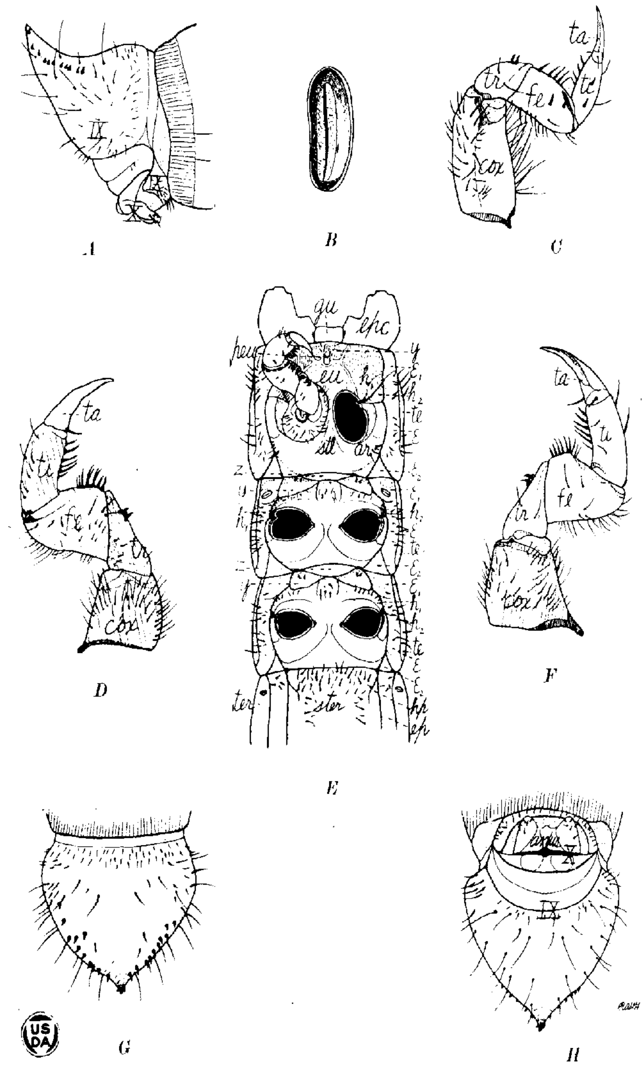
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PLATE 2

Eleodes suturalis

A.—Pygidium of larva, side view: *IX*, *IX*, ninth abdominal ("pygidial") segment, dorsal and ventral parts; *X*, tenth abdominal ("anal") segment, showing upper and lower lips.

B.—First thoracic spiracle of larva.

C.—Left mesothoracic leg of larva showing posterior face: *cox*, coxa; *tr*, trochanter; *fe*, femur; *ti*, tibia; *ta*, tarsus, claw-shaped.

D.—Left prothoracic leg of larva, showing anterior face: *cox*, coxa; *tr*, trochanter; *fe*, femur; *ti*, tibia; *ta*, tarsus.

E.—Ventral view of part of head, of thoracic segments, and of anterior portion of first abdominal segment of larva: *epc*, epicranium; *gu*, gula; *y*, presternum; *peu*, preeusternal subdivision of eusternum; *eu*, eusternum; *stl*, sternellum; *z*, poststernellum; *ar*, articulating membrane of leg; h_1, prehypopleurum; h_2, posthypopleurum; e_1, preepipleurum; e_2, postepipleurum; *te*, thoracic tergite; *ster*, sternal shield of abdominal segments; *hp*, abdominal hypopleurum; *ep*, abdominal epipleurum; *ter*, abdominal tergite.

F.—Left prothoracic leg of larva showing posterior face: *cox*, coxa; *tr*, trochanter; *fe*, femur; *ti*, tibia; *ta*, tarsus.

G.—Pygidium of larva, dorsal view.

H.—Pygidium of larva, ventral view: *IX*, ninth abdominal ("pygidial") segment, ventral part; *X*, tenth abdominal ("anal") segment, showing upper and lower lips; *anus*, anus.

THE EGGPLANT LEAF-MINER, PHTHORIMAEA GLOCHINELLA ZELLER[1]

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INTRODUCTION

Although one finds many references to *Phthorimaea operculella*[2] Zeller, a member of the microlepidopterous family Gelechiidae, in publications relating to economic entomology, the congeneric *glochinella* Zell. has received little attention. This no doubt is due to the relative economic importance of the two species, for whereas *operculella* is recognized as an important enemy of potato and tobacco in many parts of the world, being known as the potato tuber moth and the tobacco splitworm, the larva of *glochinella* seems to have been recorded in literature as feeding only on the leaves of a weed, *Solanum carolinense*. It should be mentioned, however, that this species was reared years ago from tomato leaves received from C. F. Stahl, Spreckels, Calif., and more recently from tomato leaves from Brawley, Calif., and from Los Mochis, Sinaloa, Mexico, by Dr. A. W. Morrill.

The writer has found *Phthorimaea glochinella* to be a common, though not serious, enemy of eggplant in Louisiana. Since no extended account of its life history or habits has been published, and since *operculella* also feeds on eggplant (*5, p. 14; 6, p. 3*)[3] and *Solanum carolinense* (*6, p. 3*), it is quite possible that *glochinella*, especially in the larval stage, has at times been mistaken for *operculella*.

HISTORY AND DISTRIBUTION

Phthorimaea glochinella was described by Zeller (*9, p. 263–264, Pl. 3, fig. 18*) in 1873 from specimens collected in Texas, being placed in the genus Gelechia. In the same year, Chambers (*3, v. 5, p. 176*), under the name of *Gelechia solaniella*, gave a short description of a larva and the mines made by it in the leaves of *Solanum carolinense*. In 1881 Miss Murtfeldt (*7, p. 244–245*) described *Gelechia cinerella* from Missouri. Later (*8, p. 139*) finding *cinerella* preoccupied, she renamed it *inconspicuella*. In 1902 Busck (*1, p. 502*) placed *solaniella*, *cinerella*, and *inconspicuella* under *glochinella* as synonyms; and in 1903 (*2, p. 822*) he published a full synonymy of this species with bibliography and notes.

Carl Heinrich and August Busck have kindly furnished the following list of localities from specimens in the United States National Museum: Covington, Ky. (Aug. Busck); Kirkwood, Mo. (M. E. Murtfeldt); Claremont, Calif. (C. F. Baker); Brawley, Calif. (A. W. Morrill); Brownsville, Tex. (H. S. Barber); Boulder, Colo. (T. D. A. Cockerell); Wicomico Church, Va. (P. L. Boone); Norfolk, Va. (C. H. Popenoe); Baton Rouge, La. (T. H. Jones); Sinaloa, Mexico (A. W. Morrill).

[1] Accepted for publication Nov. 1, 1923.
[2] Order Lepidoptera, family Gelechiidae.
[3] Reference is made by number (italic) to "Literature cited," p. 570.

Journal of Agricultural Research, Washington, D. C. aik

Vol. XXVI, No. 11
Dec. 15, 1923
Key No. K-121

ADULT

The following translation of Zeller's (*9, p. 263-264, Pl. 3, fig. 18*) original description has kindly been made by Dr. Adam Böving, of the Bureau of Entomology, United States Department of Agriculture. It will be noted that the last sentence refers for the most part to the male genitalia:

Head and palpi pure white; terminal joint with two black spots; antennæ with white and fuscous annulations; fore-wings ochreous gray, spotted with ashy gray. Male with anal abdominal segments armed with two lateral clavate projections.

It agrees with *operculella* in color of the body parts, only on the head and thorax somewhat more gray. Antennæ distinctly light and dark annulated. Fore-wing ochreous-yellowish gray, dusted over all with gray, so that only ill-defined spots can be seen, among which none of the ordinary discal spots or fasciæ stand out. The gray cilia are darker dusted at the base than in *operculella*. Hind-wing a trifle broader than fore-wing, pointed; below apex a slightly incurved posterior margin. Abdomen brownish gray; ventral surface very light, dull yellow; anal segment of the female yellowish, longitudinally conical with projecting ovipositor; in the male it is hardly as long as the two preceding segments together, the wider side dull ocher-yellow haired, forming a half-cylinder on the middle of which above is situated longitudinally a thin, pointed, gray, apically light-yellow cone ("kegel") (instead of the upper cover of *operculella*); on each side projects over it a thin stylus bent like an S, the yellowish end of which is thickened and then pointed and curved like a hook sideways and inwardly.

Habitat: Texas (Belfrage). One good obvious pair; male taken September 18; female July 16; in my collection.

The moth is shown in Plate 1, A.

Graf (*5, p. 12*), in treating of *Phthorimaea operculella* as a potato pest, states that it has a wing expanse of 12 to 16 millimeters. Adults of *Ph. glochinella* that have been seen by the writer had a wing expanse of only 10 to 12 millimeters. They were, however, reared specimens and because of this, and the fact that Morgan and Crumb (*6, p. 2*) found moths of *operculella* reared from potato to be larger than those reared from tobacco, it is possible that there is not so great a difference in the size of the two species as these figures would indicate.

EGG

The recently laid egg is flaccid, dull, translucent white. In shape it approaches that of a cylinder with rounded ends. Under the microscope the surface is seen to be delicately reticulated.

Ten eggs gave an average length of 0.343 millimeter, ranging from 0.304 to 0.367 millimeter, and an average width of 0.193 millimeter, ranging from 0.160 to 0.208 millimeter.

LARVA

The larva (Pl. 1, B) is somewhat semicylindrical in shape, the dorsal surface being convex and the ventral surface flattened. The body gradually tapers from the first abdominal segments to the posterior end and is plainly constricted at the junctures of the segments. The head is flattened dorso-ventrally and in living specimens is often in part telescoped within the thorax. The surface of the thoracic and abdominal segments is dull in appearance, due to the minute, close-set granules with which it is covered. There are five pairs of prolegs.

The newly emerged larva is translucent white except for the head and thoracic shield, which in all stages are of a brownish color. Later the larva becomes of a brownish or greenish white, at which time the small dark tubercles, armed with the colorless setæ, are most apparent. Larvæ in later stages of development take on a beautiful dark blue or dark green color.

The thoracic legs are light in color. Graf (*5, p. 10*) has stated that the thoracic legs of *Phthorimaea operculella* are black and in alcoholic specimens (in which the body color is lost) of the two species that the writer has seen this difference is very apparent.

Full-grown larvæ measured about 8 millimeters in length. Graf (*5, p. 10*) states that the larvæ of *Phthorimaea operculella* measure from 9.5 to 11.5 millimeters when full grown, while Morgan and Crumb (*6, p. 4*) give their length as from 7 to 1[illegible] millimeters.

PUPA

The pupa (Pl. 1, C) is spindle-shaped, being widest across the thorax. The head is rounded and the abdomen tapers to the posterior extremity. The surface shows numerous minute punctures and small wrinkles. On the head and thorax the punctures are for the most part in impressed lines, while on the abdomen they are more evenly distributed. On the dorsal surface of the anal segment there is a short, stout elevation that ends in a hook. This segment also bears about 14 spines, with hooked ends, arranged in a circle. Small hairs also occur at intervals over the surface of the head and abdomen.

Pupæ have been seen, apparently just formed, that were of a deep blue color. More mature specimens are dark brown.

Pupæ vary considerably in size, ranging from 3.43 millimeters in length and 1.05 millimeters in width to 5.19 millimeters in length and 1.76 millimeters in width.

HABITS

Moths confined with growing eggplants and provided with sweetened water deposited eggs singly on both surfaces of the leaves. They were not firmly attached to the leaf surface.

Chambers (*3, v. 5, p. 176*) and Murtfeldt (*7, p. 244*), besides giving a short description of the larva, have also given brief attention to its mining habits. So far as observed, the mines in eggplant (Pl. 1, D) and *Solanum carolinense* are always along the edge of the leaf. A number of larvæ sometimes work in a single leaf and at least two have been found using what were apparently parts of the same mine. The mined portion of the leaf has the appearance of a dry, oftentimes puffy, blotch, the older mined area being dead and brown. The leaf becomes distorted about the mine and sometimes curls over it, but no silk is apparent on the leaf surface. The larva removes the parenchyma and constructs a firm silken tube, in which it is often found, within the mined area.

In its larval habits *Phthorimaea glochinella* apparently differs from *Ph. operculella* in that it feeds entirely within the leaf, not leaving the mine to roll the leaf or feed on other portions of the plant. The fact that the mines seem invariably to be made along the edge of the leaf is also a habit not shown by *operculella*, and Morgan and Crumb (*6, p. 4*) state that the larva of *operculella* shows no tendency to form a firm, cylindrical, silk-lined tube.

When full grown the larva constructs a loose, silken cocoon in which to pupate. In rearing cages these have been found just below the surface of the soil and among remnants of dead leaves on the soil surface. Observations made in the field indicate that this is the habit under natural conditions.

The period of incubation of eggs kept in a well-ventilated insectary at Baton Rouge during June was about 7 days. On June 21 larvæ that had just issued were placed on eggplant leaves in the insectary and from these moths began to issue on July 15, giving a period of 24 days for the combined larval and pupal stages. As larvæ have been taken from leaves in the field from early May to the middle of November, there may be several broods during a year. The winter months are apparently passed in the pupa stage.

NATURAL ENEMIES

In writing of *Phthorimaea operculella*, Graf (*5, p. 32*) states that when this species works as a leaf-miner its numerous parasitic enemies do much to keep it in check. Parasites apparently play an important part

in the control of *Ph. glochinella* in Louisiana. The following species of Hymenoptera[4] have been reared from *glochinella* larvæ:

Chelonus phthorimaeae Gahan.	*Sympiesomorphelleus bicoloriceps* Gir.
Orgilus mellipes Say.	*Bassus* sp.
Bassus gibbosus Say.	*Apanteles* sp.

Their numbers vary considerably during the months when *Phthorimaea glochinella* larvæ occur in the field, though they are usually more abundant during the fall. The first three species named have issued in greatest numbers.

It has not been ascertained whether these species of Hymenoptera are primary parasites, although Graf (*5, p. 33, 42*) records *Bassus gibbosus* and a species of Apanteles as being parasitic on *Phthorimaea operculella*. He also (*5, p. 40*) lists *Chelonus shoshoneanorum* Vier. as a parasite. More recently Gahan (*4, p. 199*) has stated that the species Graf figured under this name was *Chelonus phthorimaeae*.

In addition to the reared species mentioned above, a solitary wasp, *Ancistrocerus fulvipes* Saussure, of the family Eumenidae[5] has been observed by C. E. Smith to remove larvæ from their mines in the leaves of eggplant. The wasp inserted her ovipositor into the mined area, forcing the larva to move about in the mine. When it reached a point where there was an opening in the leaf surface, the wasp grasped the larva with her jaws and removed it.

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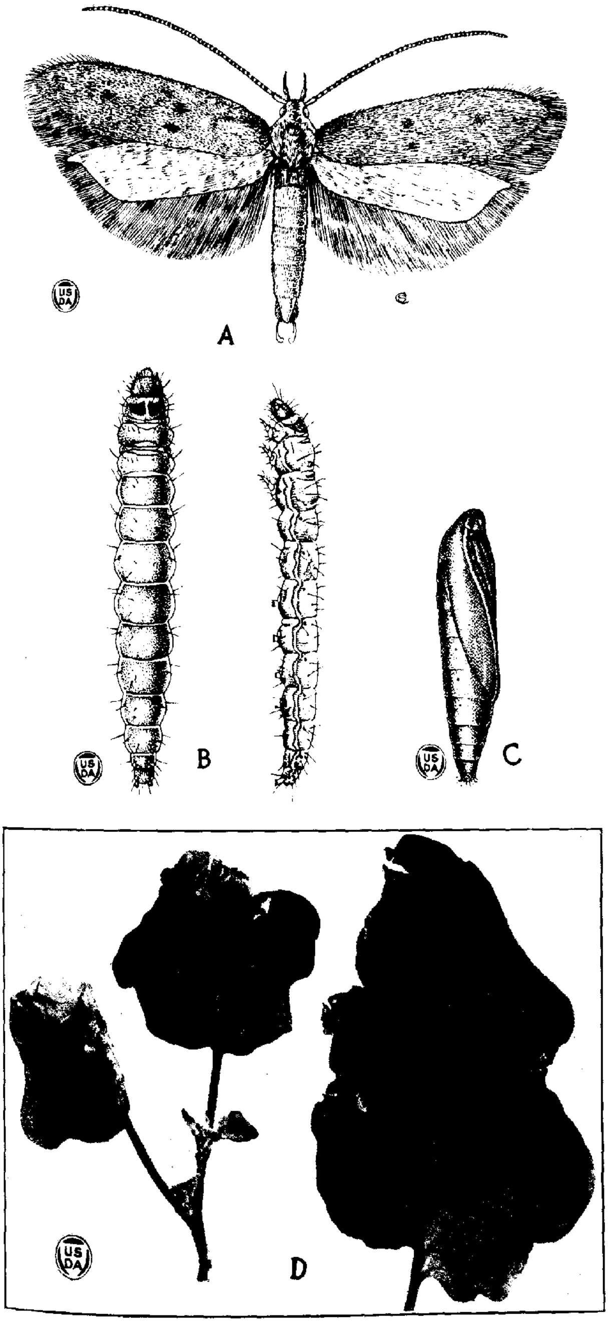
[4] All determined by A. B. Gahan, of the Bureau of Entomology, United States Department of Agriculture.
[5] Identified by S. A. Rohwer, of the Bureau of Entomology, United States Department of Agriculture.

PLATE 1

Phthorimaea glochinella

A.—Adult male, enlarged approximately eight times.
B.—Larva; dorsal view at left, lateral view at right. Enlarged about eight times.
C.—Pupa at left, enlarged about ten times.
D.—Work on leaves of eggplant.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